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UTILIZATION HOUSE TECHNICAL SUPPORT PACKAGE  
SUMMARY OF RESULTS AND HOUSE DESCRIPTION  
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# Technical Support Package for Tech Brief LAR - 12134



## NASA Technology Utilization House SUMMARY of RESULTS and HOUSE DESCRIPTION

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# NASA Technology Utilization House

A "house of the future" is ready today.

Langley Research Center, Hampton, Virginia

The NASA Technology Utilization House (Tech House), constructed at Langley Research Center, was designed and built to demonstrate how the application of aerospace technology could advance the building industry in residential construction. Tech House is a single level structure of contemporary design which is comprised of two square modules connected by a hallway and contains approximately 140 m<sup>2</sup> (1,500 ft<sup>2</sup>) of living space. One module consists of a living room, dining area, and kitchen; the other, three bedrooms and two baths. The connecting hallway has an entry vestibule and a laundry room. In developing Tech House, NASA incorporated the latest technology and used special features when either the initial cost could be recovered in energy savings over the useful life of the feature or if it provided a specific benefit such as personal or structural safety. The one other criterion for application of advanced technology was that the feature was projected to be commercially available within five years.

It is forecast that within five years the house with all its special features can be built commercially for approximately \$45,000 (based on 1976 costs). With the incorporation of solar energy, energy efficient appliances, and the water reuse system, it is predicted the homeowner would save approximately \$20,000 in utility costs over a period of twenty years, after recovering the additional cost of these special features. (This forecast is based on a ten-percent annual increase in utility costs.)

The following special systems and features, most of which are an outgrowth of NASA's aerospace technology, have been incorporated into Tech House:

## Heating and Cooling System

- Solar collectors on the roof are

used, together with nighttime radiators, two wells, and a heat pump, to supply major heating and cooling requirements.

- Additionally, the fireplace is outfitted with a duct system to bring in combustion air from the outside, and fire grate water coil, enabling the accumulation and storage of heat for later distribution.
- Exterior retractable shutters provide energy savings when closed by preventing heat loss during the winter and heat gain during the summer and, at the same time, function as a security measure.
- A nonflammable, nonpetroleum based foam provides highly efficient insulation, supplemented by metal exterior doors which have a thermal break, polystyrene core and magnetic weather stripping.

## Water Recycling System

- A 50-percent reduction in water consumption is attained through use of low-profile water fixtures and a water reuse system which collects waste water from the

shower, bathtub, bathroom sinks, and laundry in a holding tank where it is chlorinated, filtered, and recycled for toilet flushing.

## Hot Water System

- Solar energy heats the water used in the domestic hot water system.

## Security System

- Interior security is provided by detectors at doors, windows, and under carpets which set off an alarm when an intrusion occurs.
- An exterior security system uses a seismic device to sound an alarm when an intruder approaches within 80 m of the house.
- A smoke detector is used to sense the presence of combustion products and sound an alarm.
- A battery charged by a solar cell provides power for a driveway spotlight and emergency lighting. The smoke detector and security system may also be powered by the solar-charged battery.
- A tornado detector is attached to the television screen and sounds an alarm upon the appearance of a



NASA's Tech House at Langley Research Center incorporates solar heating, cooling, and hot water. A security system includes intruder and fire alarms, a tornado detector, and emergency lighting. A water recycling system and energy-saving lighting fixtures help reduce the homeowner's costs.

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tornado within a radius of 18 mi.

**Additional**

- Thermistors installed in lamp sockets significantly increase the life of the light bulbs by a minimum of 300 percent.
- Seat cushions are made of an advanced foam rubber that contours to a body shape, thereby distributing weight evenly over the contact surface.
- Flat conductor electrical wiring, covered with plastic baseboard, which has greater current capacity was installed after the building was

completed and the carpet installed.

These features are all examples of the innovations utilized in the construction of the Tech House to demonstrate the application of advanced technology to minimize energy and water consumption and provide for the comfort and safety of the homeowner and his family.

*This work was done by the  
Technology Utilization Office of  
Langley Research Center.*

*While no patent action is contemplated by NASA on the Technology Utilization Home as such, many of the components and systems included in the house are covered by patents. Some components were developed by private industry and industry owns those patents. Inquiries regarding which items are patented and concerning rights for the commercial use of these inventions may be directed to the Patent Counsel, Langley Research Center, Mail Stop 279, Hampton, VA 23665. Refer to LAR-12134.*

## PREFACE

Current consumer awareness of energy shortages and limited resources have required that all possible means of conservation be applied. The "home" is a large consumer of energy; thus the homebuilding industry is being challenged to apply all possible conservation measures. New technology and materials should be used as soon as it is economically feasible to do so.

August 1979

NASA TECHNOLOGY UTILIZATION HOUSE  
SUMMARY OF RESULTS AND HOUSE DESCRIPTION

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## INTRODUCTION

The Technology Utilization House (Tech House) was designed and constructed at NASA Langley Research Center, Hampton, Virginia, to demonstrate to the building industry and the public the benefits of aerospace technology and other new technology that are presently available or will be in the very near future. Use of solar energy, conservation of energy and of water, safety, and security were incorporated in the design of the house.

A committee consisting of representatives from the Department of Housing and Urban Development; the National Association of Home Builders Research Foundation, Inc.; the National Bureau of Standards; the Consumer Product Safety Commission; and NASA was formed to evaluate the items to be incorporated into the house and to assist in the design of the house. In addition, an architectural engineering team was employed to investigate energy conservation ideas, determine cost effectiveness of new materials and systems, and prepare specifications and drawings for the house. The criteria for the selection of items and systems to be included in the house required that they should be commercially available within 5 years and that the energy saving systems would pay for themselves within 20 years or within their life cycle.

As a basis for the determination of the normal water and energy requirements for a single-family home, use was made of a study conducted for HUD of a residence in the Baltimore-Washington area (designated herein as the "Reference House"). Results of this study were used to determine the energy saved in the Tech House.

The Tech House was constructed during the spring of 1976. After completion, the house was open to the public while its systems were being checked out. All systems were operational when the family (Dr. Swain; his wife, Elaine; daughter, Carol; and son, Charles) moved in. All the systems were monitored to insure proper operation, and data were collected during the 1-year occupancy by the family. After the family moved out, the house was once again opened to the public.

Results obtained during the family live-in period, comments on the acceptance of the various energy-saving systems by the family, and suggestions for improvement of the systems are presented.

The equipment and materials used in the Tech House are now on the market or will be soon. Sources for these items are given in the appendix. All comments made on the equipment and materials in the paper are based on the usage and behavior in the Tech House and should not be considered to be endorsements of the products.

It should be pointed out that energy-conserving homes are most efficient when carefully designed to fit specific sites with their particular characteristics of access, orientation to sun and winds, history of weather conditions, and thermal requirements. For this reason, the Tech House was not intended to be,

and should not be, considered a prototype suitable for all locations. Instead, the Tech House should be viewed as a demonstration model and research facility containing many individual systems, components, products, and ideas which can be applied in some degree to all housing.



## DESCRIPTION OF THE HOUSE

The Tech House is a one-story structure of contemporary design. (See figures 1 and 2.) It is of frame construction with fir plywood siding and dry walls on the inside. The house contains approximately 1,600 square feet of living space. Two rectangular modules connected by a 7-foot wide foyer with entry vestibules in the front and rear of the house comprise the living area. These modules have gable roofs on which the 18 solar collectors (16 for the heating system, 2 for the domestic hot water system) are located.

A third rectangular module comprises the garage which houses the data-gathering instrumentation, computer, and heat pumps. A similar home occupied by a family would not require the data-gathering instrumentation and the large computer. Also, the heat pumps would be placed outdoors and thereby allow the full use of the garage by the family. On the gable roof of the garage is located the solar cell which charges a 12-volt battery with solar energy. The battery is used for the emergency lights and could also be used for the security system.

The floor of the house is a prefabricated, 2-inch-thick, reinforced concrete slab above a 3-foot crawl space and has 6 inches of gypsum foam insulation on its underside. The floor was delivered and installed in 7- by 14-foot sections. The walls were insulated with 5½ inches of Tripolymer foam. The attic was insulated with 7½ inches of the same foam. Large ventilation louvers provide cooling of the attic during the summer. The roof was shingled, except in the flat areas.

The exterior doors have steel surfaces with polystyrene foam cores and magnetic weatherstripping. An adjustable sill provides a positive seal against the weatherstripping. All windows were aluminum framed with plastic, low-thermal-conductivity separators between the inside and outside areas of the frame. They are also double glazed. External shutters were added to further reduce the heat loss in winter and the heat gain in summer.

The floor coverings in the house vary. The kitchen flooring is foam-backed vinyl with a urethane coating; the bathrooms have ceramic tile floors. The foyer and entrance area floors are of slate, and all other rooms are carpeted.

Several items intended primarily for security and comfort of the occupants were included, such as an emergency lighting system, a sonic transmitter to turn on outside lights, interior and exterior security systems, a smoke alarm, a tornado alarm, and self-locking hinges.

The emergency lighting system is powered by a standard 12-volt battery which is kept charged by a solar cell. In the case of a power outage, it supplies light to the kitchen, living room, hallway, and foyer. This system was used twice by the family during the live-in period.

A manually operated sonic transmitter turns on the entrance light from a distance of 30 feet and provides a lighted entrance on return without burning a light during a period of absence.

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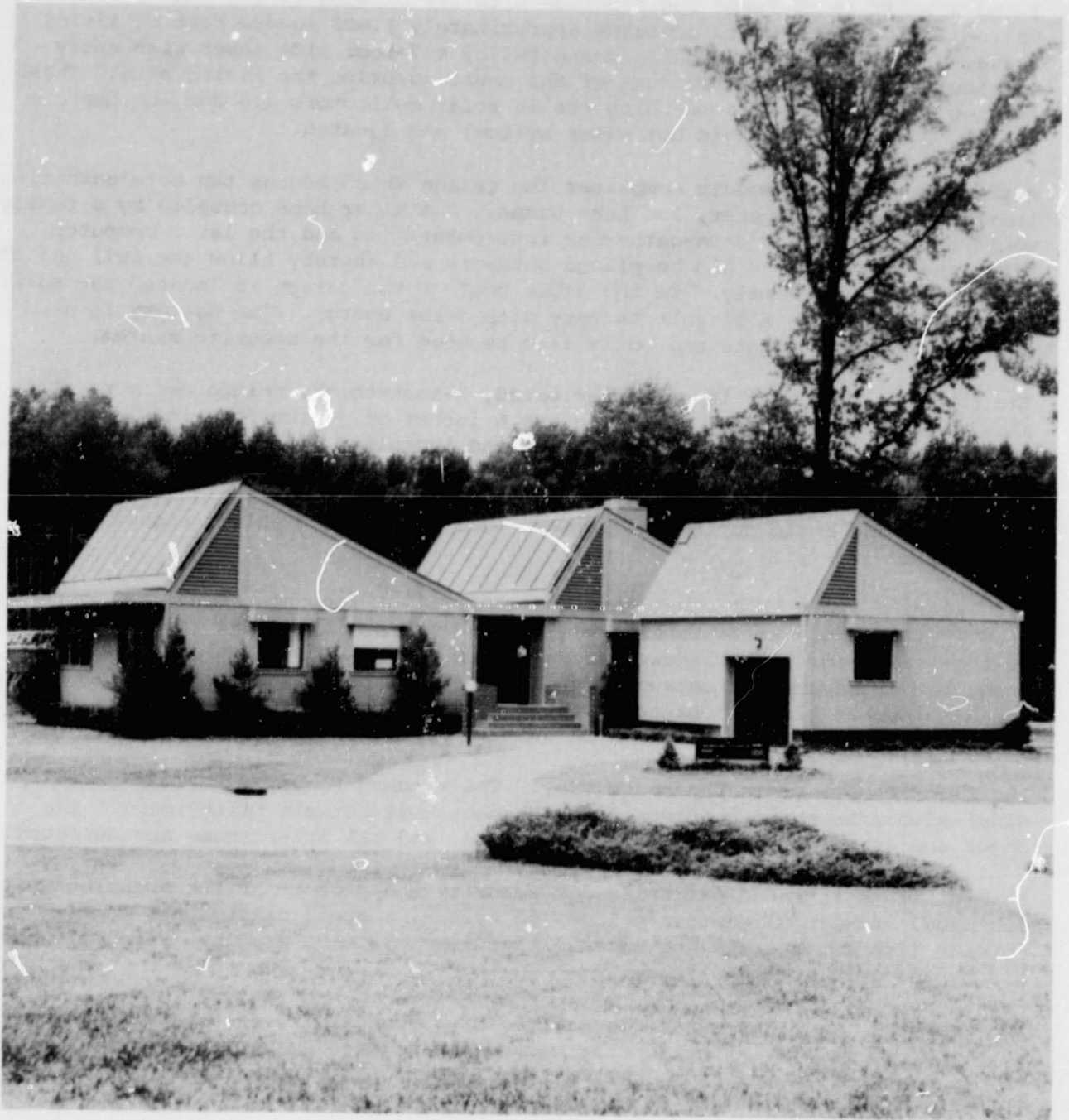


Figure 1 - The Tech House

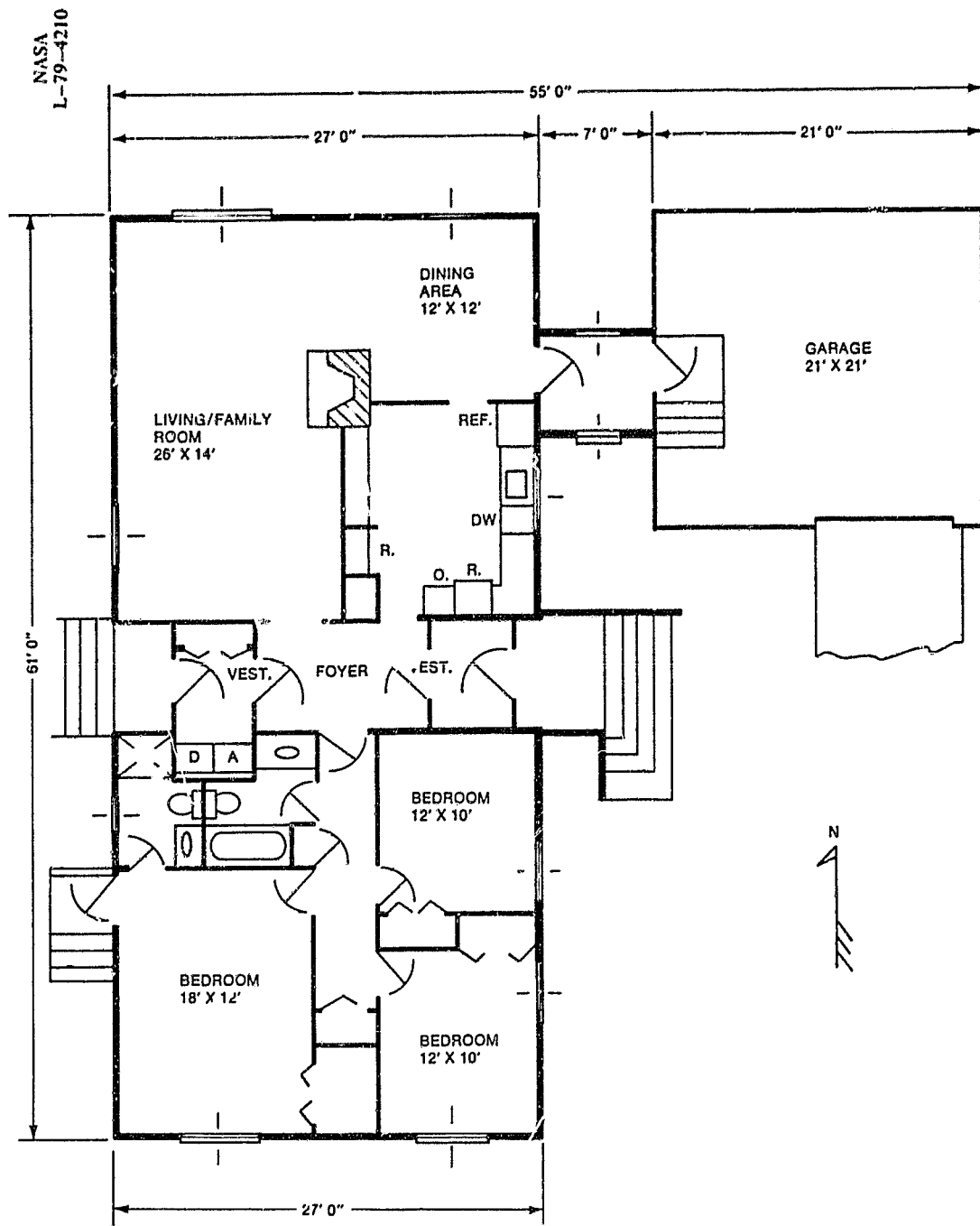


Figure 2 - Tech House Floor Plan

The interior security system is activated whenever an intruder opens any door or window, removes any screen, or walks over sensors installed on the floor under the rugs. To arm the system, a coded number is entered on the control panel, and a time delay permits the person to leave or return to the house without setting off the alarm.

A seismic detector, which uses an FM radio to alert occupants of a person walking outside the house, was not used by the family. This system is more suitable for a house located on a large piece of property (several acres). On a small lot, such as that of the Tech House, the detector cannot be set to exclude vibrations from normal nearby traffic.

A standard smoke alarm was provided to alert or wake everyone in case of a fire and to allow them time to vacate the house before the fire becomes a threat to life.

The tornado detector is a light-sensitive device in a suction cup which is attached to the television picture tube. With the TV on an unused channel and the screen darkened, it sounds an audible alarm if a tornado is within 18 miles. Since the Tech House is not in an area subjected to tornadoes, this item was not used during the live-in test.

Self-locking hinges were used, but not tested, in the house. These hinges prevent the removal of doors after hinge pins are removed. They are needed on doors that swing outward and would primarily be used on public buildings.

Two items, electrical in nature, were also included: flat conductor cable within a baseboard molding and light bulb savers. The flat-conductor-cable electrical system was installed in the living area and dining room after the carpets were in place. It was not necessary to run wires through the walls. A major benefit of such a system is in refurbishing old homes, since the new wiring can be installed in a baseboard system and not require the removal of the wall's sheathing.

The bulb savers, which the manufacturer claims extends the life of the light bulb by 300 percent, were used in two incandescent lamps. They eliminate the surge of current to the cold filament in a bulb when the light is turned on. No tests were conducted to confirm the manufacturer's claim; however, the two bulbs in the house that contained bulb savers did not burn out during the 1-year live-in test.

Many other items which were incorporated into the house for the comfort and convenience of the occupants, such as the temper foam cushions and the appliances, were not evaluated during the live-in test, since to do so would require invasion of the privacy of the family.

### ENERGY CONSUMPTION

To have a basis for comparison and to evaluate the savings possible, a Reference House in the Washington-Baltimore area on which a former study for HUD had been made was chosen. The Reference House is a two-story, 1,695-square-foot, wood-frame house with plywood sheathing, R-7 fiberglass insulation in the walls, and 5 inches of loose fill insulation in the attic. Doors are of wood. Windows and glass patio door are single glazed.

One of the goals in the construction of the house was to substantially reduce the energy and water consumption. A comparison of the energy estimated for the Reference House and that projected for the Tech House is given in the following table:

<u>Energy Consumption</u>	<u>Reference House (kwh)</u>	<u>Projected for Tech House (kwh)</u>
Central Heating	29,300	6,000
Central Air Conditioning	3,600	2,100
Water Heating	4,380	1,500
Lights )	2,000	1,000
Appliances ) Baseload	5,609	3,400
Miscellaneous)	<u>1,111</u>	<u>1,000</u>
Total	46,000	15,000

Note that the energy consumption was expected to be about one-third that of the Reference House.

The savings experienced during the family occupancy of the house are illustrated in figure 3. The actual energy consumption of the Tech House during the live-in test as compared with the results from the Reference House is about one-half, as shown in table I.

Energy for domestic hot water and baseload are highly user-determined, and realistic savings cannot be determined by comparisons with the Reference House.

For the amount of domestic hot water used in the Tech House, it would require 6,392 kwh of electricity to heat in the absence of supplemental energy. However, at the Tech House only 4,176 kwh were used with the balance, 2,226 kwh, supplied by solar energy. This result shows an actual savings of about 35 percent.

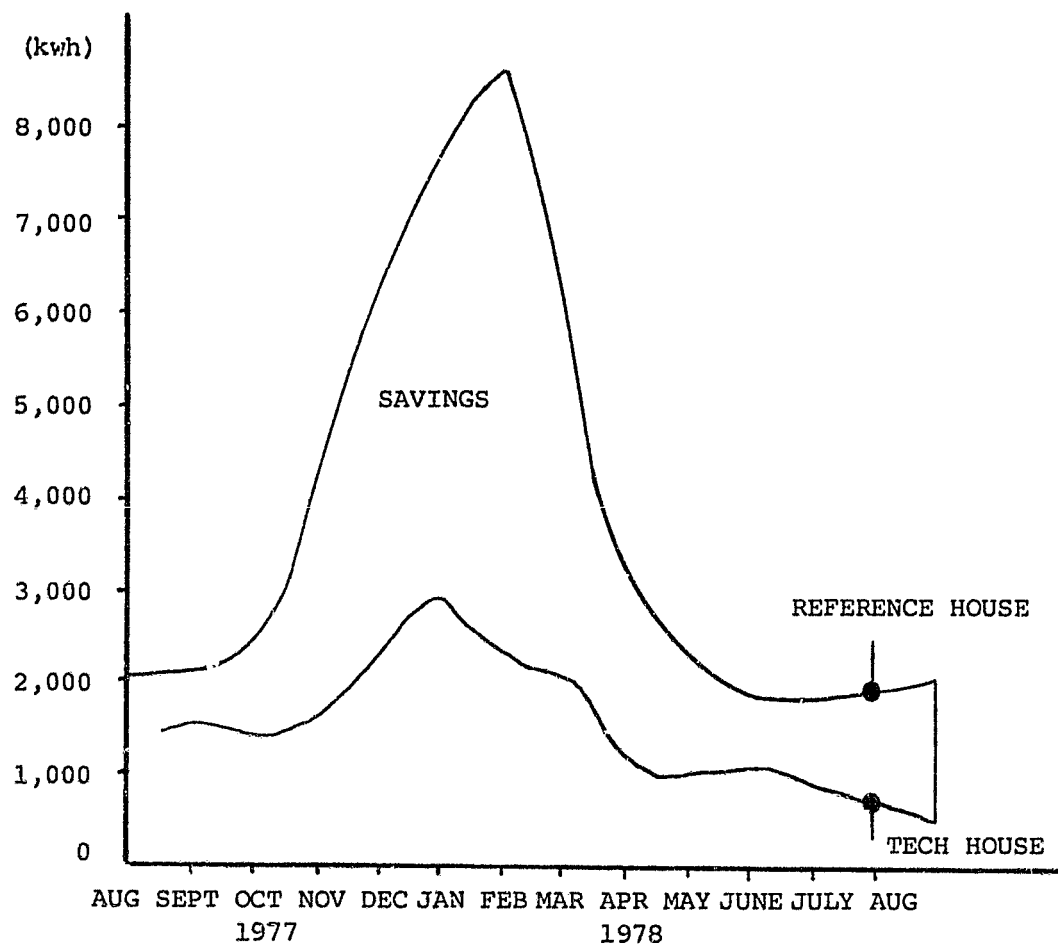


Figure 2 - Comparison of Energy Consumption for Reference House and Tech House

Table I - Breakdown of Electrical Energy Usage

Item	Reference House (RH) (kwh)	Tech House Load (Annual)			
		Predicted Use (kwh)	Predicted Savings Relative to RH (%)	Actual (kwh)	Percent Saved Relative to Reference House
Hot Water	4,380	1,500	66	4176.4	5
Central Heating	29,300	6,000	80	6087.7	79
Central Air Conditioning	3,600	2,100	42	2732.0	24
Baseload (lights, appliances, etc.)	8,720	5,400	50	6938.4	20
Total	46,000	15,000	66	19935.0	57

A study made prior to the tests at the Tech House indicated that substantial savings in water consumption could be made by using water-saving fixtures, such as restrictors in the shower heads and low-profile water closets, and by using recycled waste water for toilet flush. The water-consumption saving projected for the Tech House was 40 percent from the gray-water reuse system and 10 percent from the water-saving devices. Actual savings were 27 percent from the water reuse system and 9 percent (estimated) from the water-saving devices for a total of 36 percent. Both water usage and savings are significantly influenced by family lifestyle.

### FEATURES THAT AFFECT ENERGY USE

Many features of a house affect the amount of energy used but do not in themselves use energy. Included in this category are the structure, insulation, types of doors and windows, skylights, architectural features, such as size and location of overhangs, orientation of the house, trees, shrubs, and the exterior color. Because of the sun's position at various times of the year, a house orientation with short eastern and western walls and long northern and southern walls is desirable.

Because of site restrictions, the Tech House was designed with long eastern and western walls and short northern and southern walls. An overhang was added to shade the windows on the southern wall during the summer but allow the sun to enter the windows during the winter months. Thermal shutters were added to the windows to reduce the loss of heat from the windows at night during the heating season and to provide a shield against solar heat in the summer. Without shutters, an overhang or some means of shading is needed. The eastern and western walls have no overhang. Trees or hedges could be planted to provide shading and a winter windbreak. Flat areas or obstructions of any type on the roof may present a problem in an area that has snow, as it will build up over the solar collectors and lessen their effectiveness.

The skylight located in the foyer of the house worked very well in the spring and fall but, like other glass areas, there was a loss of heat in the winter and a gain of heat in the summer.

The large attic ventilation louvers provided cooling of the attic during the summer. During the winter 80 percent of their area was closed to prevent possible freezing of the drain line from the solar collectors.

The shutters are effective energy savers when properly used. However, during the summer when the shutters are closed to keep the solar heat out, they darken the house, and this may be objectionable. Closing the shutters at night, both in the winter to keep the heat in the house and in the summer to preserve the air conditioned air, is acceptable. The family also found the shutters to be quite effective in reducing the noise level from outside sources.



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INSULATION

The ceiling and walls, including some interior walls that separated the zoned areas, were insulated with Tripolymer foam. The floor that was delivered in 7- by 14-foot sections contained 6 inches of gypsum foam insulation. A 4-mil, polyethelene vapor barrier was placed on all exterior walls and the ceiling before the sheetrock was installed.

The ceiling contained 7½ inches of insulation for an R value of 34. The outer walls, which were constructed with 2- by 6-inch studs on 24-inch centers, contained 5½ inches of insulation. This insulation had an R value of 25.

The amount of insulation recommended for a house is based on the geographical location of the house, which reflects the climate and the cost of fuel for the type of heating system.

To determine areas of heat loss in the house, thermograms (photographs that indicate temperature variations in pattern from white to black) were taken of all walls in the house. Thermograms were used to indicate areas of heat loss but not quantity of heat loss. A sample thermogram is presented as figure 4 which shows the west wall of the master bedroom. The fact that the wall insulation is a better insulator than the wooden studs is clearly evident.

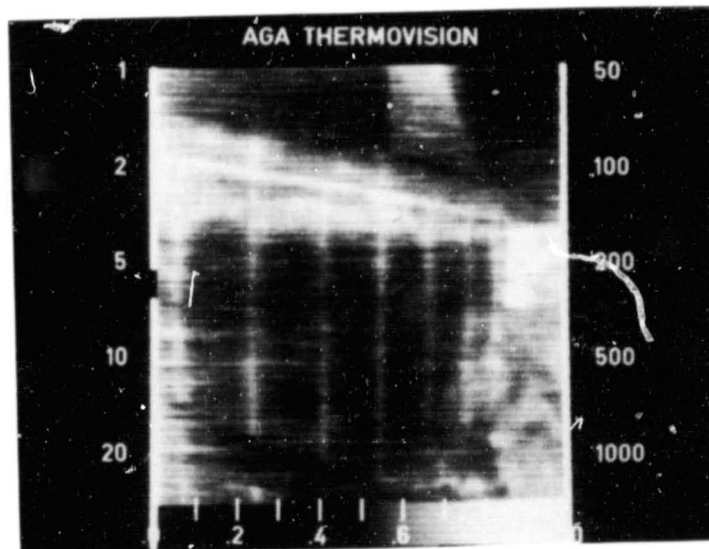


Figure 4 - Sample Thermogram

Although the house was insulated better than average homes, thermograms showed that the doors, window areas, stud areas, eaves, and baseboards were hotter than the walls (indicating higher heat losses), as one finds in surveying a home with less insulation. This result is understandable, since the walls have a higher R value than windows (including thermopane), doors, and wood which the studs, eaves, and baseboards consist of. Shrinkage of the Tripolymer foam insulation in the walls and ceiling of about 6 to 8 percent contributed to heat loss around the studs and the eaves. The door and window areas showed a higher degree of loss than the walls. The floor showed very little loss. It was estimated that the R value for the wall insulation decreased from 25 to approximately 22 as a result of the shrinkage.

Although the insulation shrank and the R value dropped, the house was still tight with an overall R value higher than that of average homes. The data indicated that about \$700 in savings during the year resulted from improvements to the thermal envelope (thermopane windows, insulated doors, vestibules, high R value insulation, etc.).

### NOISE TEST

A noise test was made at the house on December 14, 1978. For the test, a noise generator provided a 90 dba noise level 30 feet from the house (noise equivalent to that of a train). Inside the house with the shutters open, the measured levels were between 40 and 60 dba; with shutters closed, they ranged from 40 to 48 dba. The live-in family frequently used the shutters at night to reduce noise from nearby research facilities.

### WEATHER CONDITIONS

During the winter of 1977-1978 the heating degree days and the available sunshine were measured to determine whether the heat required and the solar energy available were typical of a normal year. The data for 1977-1978 are compared with the 30-year average for the Hampton Roads area of Virginia. (See figures 5 and 6.)

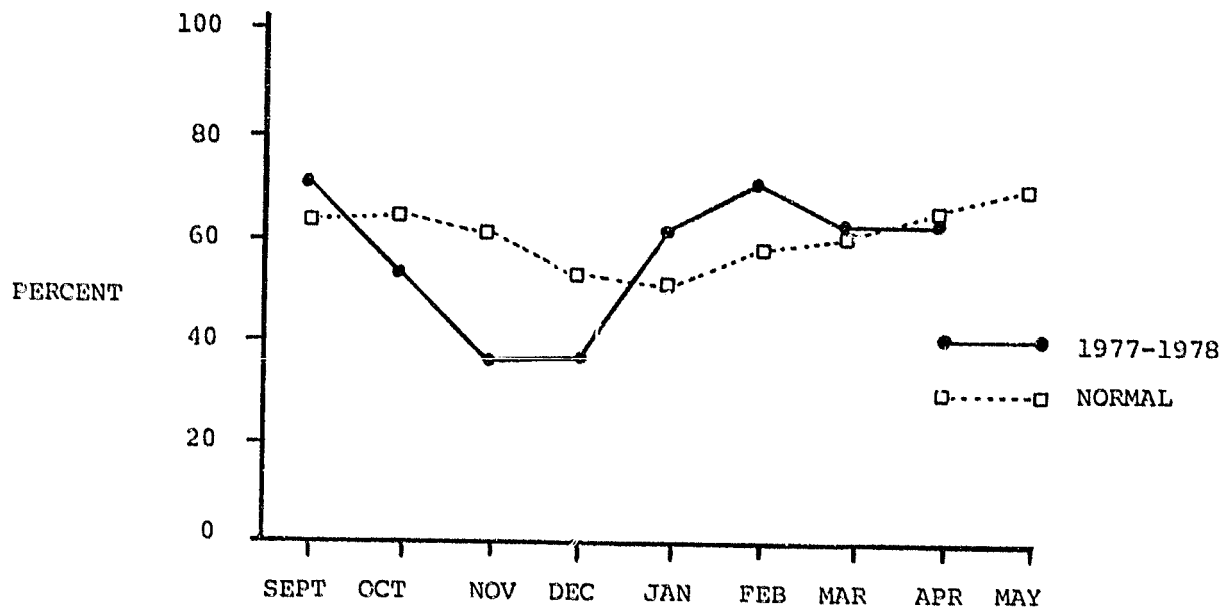


Figure 5 - Percentage of Sunshine Available Versus Normal for Area

A month-by-month comparison of percent of sunshine available for the year versus normal sunshine for the area has a significant bearing on the performance of the solar collector systems at the Tech House. During the fall and early winter available solar energy (sunshine) was considerably below normal. The impact of less-than-normal sunshine during the period was lessened for space heating considerations in that the heating degrees for the same period were also below average. The greater-than-normal available sunshine in mid and late winter was accompanied by severely cold weather.

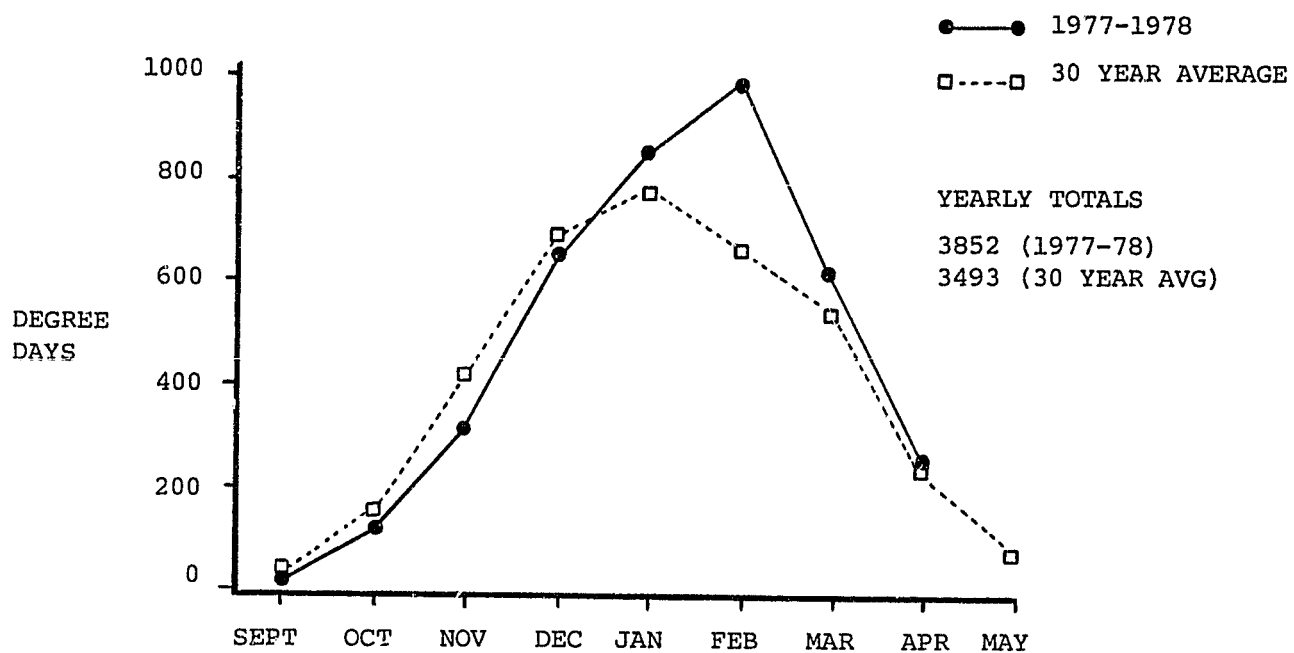


Figure 6 - Heating Degree Days Versus 30-Year Average

## HEATING AND AIR CONDITIONING SYSTEMS

### Description

Solar collectors mounted at an angle of  $58^{\circ}$  on the south-facing roof were expected to supply about 70 to 80 percent of the space heat required for the Tech House. (The preferred angle at which the collectors are mounted depends on the latitude of the house.) The glass of the solar collectors admits light and other solar radiation but traps the heat reflected from the interior. This "greenhouse" effect is experienced when you leave your car parked in the sun.

Water circulating through the collectors carries the heat to the heat exchanger, which heats the circulating air. If the heat is not needed, the hot water is diverted to a 1,900-gallon, thermal storage tank. During the night and during periods of cloudy days, this water is recirculated to heat the house. When solar-heated water (above  $95^{\circ}$ ) is not available, well water is used as the heat input to the water-source heat pump to heat the house. Using well water warmer than the outside temperature reduces the amount of electricity needed to heat the house.

Listed below are the various modes used for heating the house, in the order of preference, from an energy efficiency viewpoint.

- Solar-heated hot water directly to air duct heat exchanger
- Storage tank water (if above  $95^{\circ}$ ) to air duct heat exchanger
- Well water to the water-source heat pumps

For air conditioning, the solar collectors for space heating are cut off. Well water ( $55^{\circ}$  to  $58^{\circ}$  F) is pumped through a heat exchanger in the return air duct and drops the temperature of the return air by about  $10^{\circ}$ . The water continues on to the heat pumps and absorbs the heat from the pumps and then is put back into the ground through another well. Night radiators were placed on the north-facing roof with the anticipation that the 1,900-gallon storage tank water could be used by the heat pump during the cooling season and cooled at night with the radiators. The humidity and climate conditions prevented the night radiators from working effectively and the system was not used.

A simplified diagram of the heating and air conditioning systems is shown in figure 7. For clarity, the drain-down lines and valves are not shown.

As shown in figure 7, the system provides heat to the house from either the heat pumps or the direct duct heat exchanger. The heat pumps serve as a backup system for the solar collectors and can use either the storage tank water or the well water as a source of energy. The direct duct heat exchanger can use heated water from the solar collectors, the fireplace coil, or the storage tank as its source. When there is a fire in the fireplace, water is pumped from storage back through the fireplace water grate and returned to the storage tank if the

water is not needed, or through the direct duct heat exchanger to the tank, with the heat pump fans distributing the heat to the house. The fireplace also has an outside air source so that the glass doors can be closed and heat from the house retained.

A primary part of any heating or cooling system is the means of controlling the temperature in a house. Most homes use a single thermostat near the return air duct. This often results in unequal heating of areas of the house.

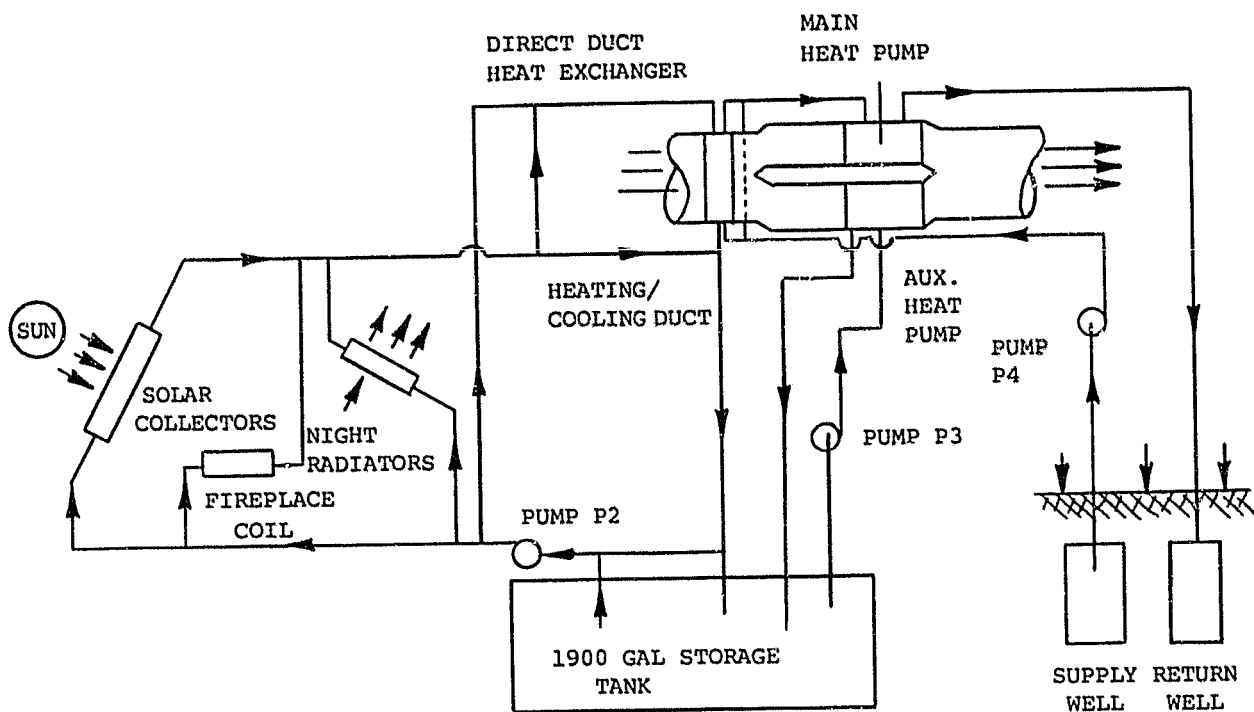


Figure 7 - Simplified Diagram of Heating and Air Conditioning Systems

In order to heat only those parts of the house that were being used, the Tech House was divided into four heating zones--each equipped with its own sensor or thermostat. Thus each zone could be heated to meet the family needs and lifestyle, and variations in the temperature for weekdays and weekends could be made. The four zones were zone 1, master bedroom and bath; zone 2, childrens' bedrooms; zone 3, hall and bathroom; and zone 4, living areas. Such zone control makes the most efficient use of the heat.

#### Performance

Solar energy provided a savings of about \$242 (at 4.4¢/kwh) for the year in space heating. There was a loss of energy from the storage tank which, if not lost, would have resulted in another \$100 (2,300 kwh) savings. Pumping costs also prevented greater savings. At an installed cost of \$25 per square foot of solar collector, the solar system would cost nearly \$10,000, which would not result in a cost payback in 20 years. Hence, for this area, hot water heating systems using solar energy do not appear to be practical, unless the installation cost could be reduced to about \$3,000 and the storage system made more efficient.

The heating and air conditioning systems were designed to provide solar and conventional heating at an energy use rate of 6,000 kwh for heating and 2,100 kwh for air conditioning. The comparable Reference House used 29,300 kwh for heating and 3,600 kwh for cooling. During the family live-in period the use of energy for heating was 1.5 percent above design estimate. However, the energy use for heating was 79.2 percent below that of the Reference House; for air conditioning it was 24.1 percent lower.

The 384 square feet of solar collectors had been expected to supply 70 to 80 percent of the heat required for the house, but they only provided 40 percent. The 70-percent figure was based on the expected degree days and the expected percent of possible sunshine. However, the winter was colder than normal and the available sunshine was less than normal. In addition, approximately 35 percent of the solar energy was of such low intensity that energy could not be collected.

The heating system includes a 1,900-gallon, concrete, underground storage tank to store the heated water to be used for the heating system when solar energy is not available. There was significant degradation of the tank insulation during the live-in test period because of a breakdown on the waterproofing used to seal the tank insulation against ground water. A greater portion of the heating energy would have been provided by solar if it were not for the greater-than-expected tank losses. If the tank had been located above ground, it would have been more accessible and its insulation could have been readily inspected and repaired. Also, if located above ground, a circulating pump, rather than a suction pump, could be used and the operating cost would be less.



## Zone Control

The heating system responded to temperature sensors located in four zoned areas of the house. Zone control has two advantages: (1) it saves energy by allowing temperatures to be reduced in areas not being used and (2) each area can be heated to the required level. A heating and cooling schedule was developed for each zone according to the family lifestyle.

With zone control heating, the temperatures throughout the house were within about 2 degrees of the sensor setting. When operated for a short period without zone control heating, temperature variances from sensor settings were as high as 10 degrees. This results from the fact that heat is provided to all areas until the coolest room is satisfied, as opposed to the zone control system where each zone is satisfied separately.

Zone control can provide a method of space heating that is both comfortable and economical. However, its use with heat pumps requires that minor modifications be made, if necessary, in order to not reduce the air supply or the heat pump capacity.

## Fireplace System

The fireplace is an integral part of the heating system of the Tech House. The fireplace has a water-cooled fire grate; a double-walled, steel firebox; and an outside combustion air supply; and is capable of heating the entire house. (See figure 8.) When the fire is burning, the warm air from the firebox and radiation can keep the living room and kitchen areas comfortable. The water heated in the grate circulates through the heating system. Approximately 50,000 btu/hr of heat can be utilized from the fireplace (38,000 btu/hr from the grate and 12,000 btu/hr from the double-walled, steel firebox and radiant heat).

During the live-in test, the family used the fireplace very little because of two problems: (1) the pumps supplying water to the grate had to be turned off after the fire went out; thus one could not go to bed while the fire was burning; and (2) the fireplace, at times, overheated the living room area and it became uncomfortable. The first problem can be eliminated with minor control modifications. The second problem could be corrected by ducting the fireplace heat to the rest of the house. The hot water from the fireplace grate could also be circulated to heat the domestic hot water.

The heating cost for the house could be lowered if the fireplace were used regularly. A water coil will provide up to 2,200 kwh of energy per cord of wood burned. Depending on the cost of electricity, the water coil will produce \$60 to \$90 worth of energy per cord of wood burned.

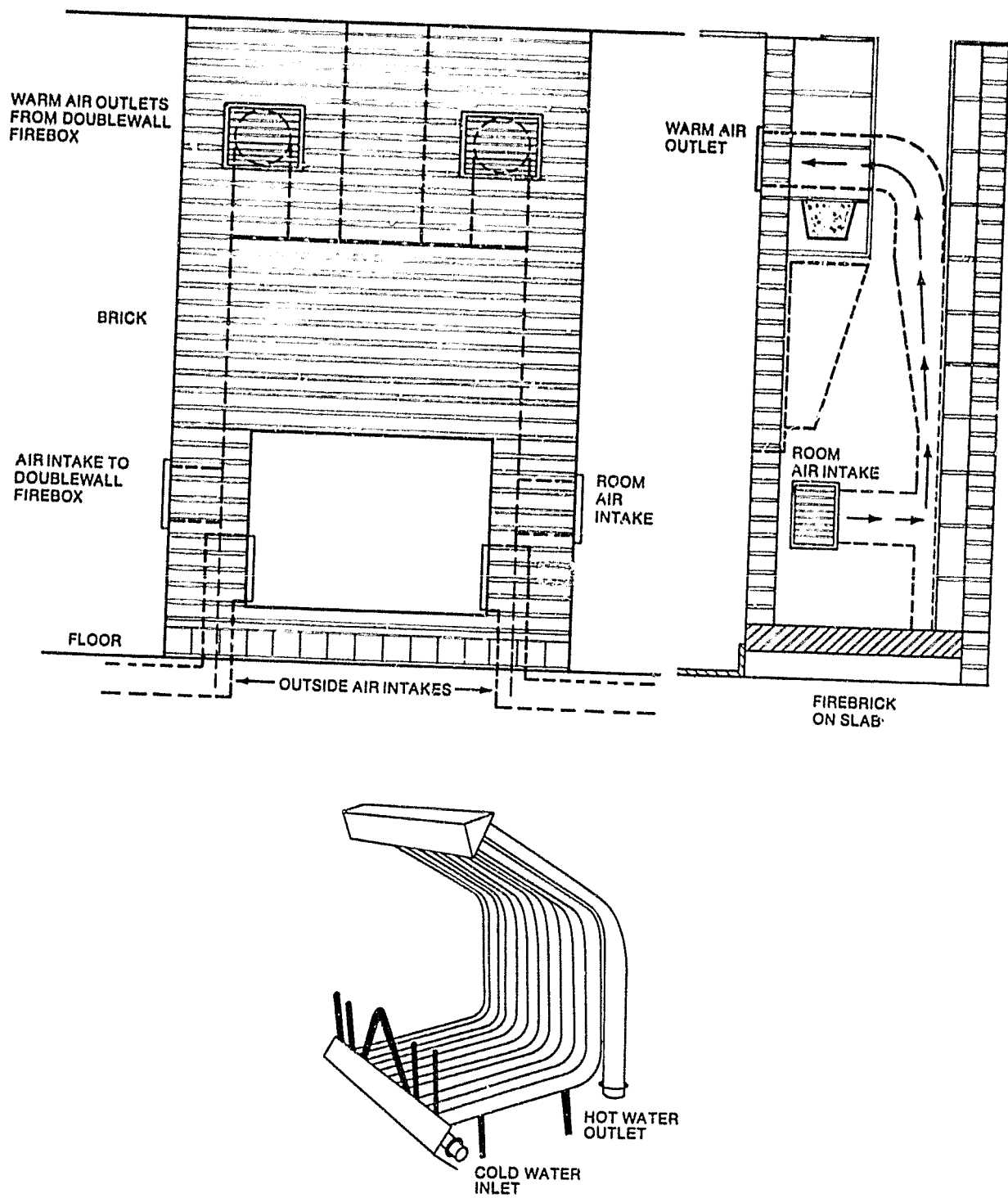


Figure 8 - Fireplace Design

### DOMESTIC HOT WATER SYSTEM

The domestic hot water system (see figure 9) consists of a 50-gallon tank which is heated with solar energy and a 42-gallon, electrically heated tank. City water enters the preheat tank where it is heated with solar energy. When hot water is required, water is provided to the user from the electrically heated tank, and water from the preheat tank is supplied to the electrically heated tank. If the water temperature in the electrically heated tank drops below the preset temperature (usually 140° F), the electric element comes on. Solar energy was expected to supply 65 to 75 percent of the domestic hot water for a family of four (approximately 80 gallons of hot water per day). Actually, the system only provided about 35 percent of the use during the live-in test. Some reasons for this difference are that the family was gone during the day when the water was being solar heated, and the storage capacity was inadequate to provide the necessary reserve. Showers were taken in the morning, and the laundry and dishes were usually done at night; as a result, the 50 gallons of solar-heated water were exhausted, and electrically heated water was required. The average daily usage per person was 16 gallons, but usage of 25 to 30 gallons per person was not unusual.

The design of the system and sizing of the components should be representative of the family and family lifestyle in order to realize the best payback on the system investment. The Tech House system design did not satisfactorily anticipate the lifestyle and water use patterns of the family subsequently selected for the live-in test. Both the solar collection area and preheat tank capacity were slightly undersized for the hot water use pattern of the family.

There were periods when hot water was not used for several days. Under these conditions the water was continuously circulated through the collectors to prevent overheating and boiling of the collector system water. The cost of the pumping energy for this situation is only pennies a day.

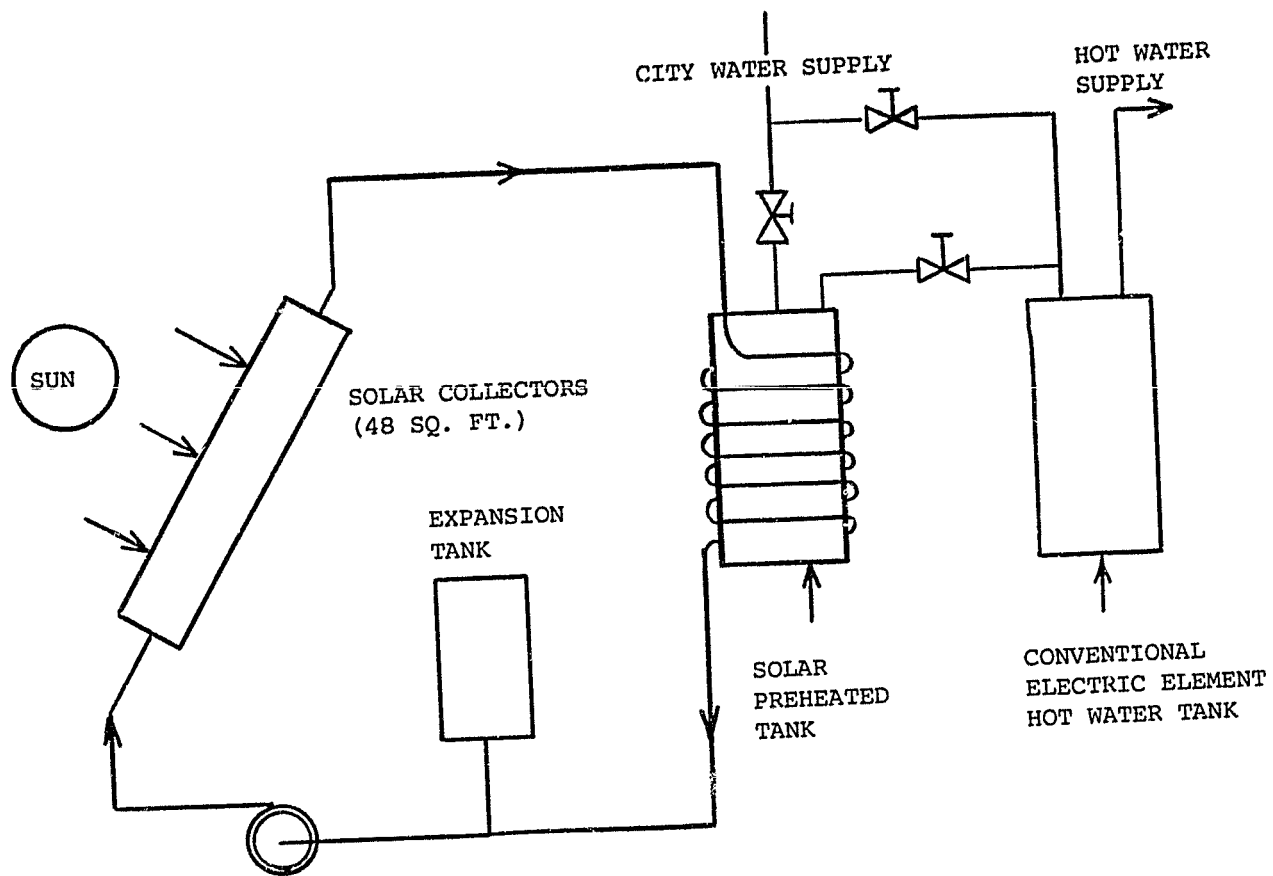


Figure 9 - Solar Hot Water System

### DOMESTIC GRAY-WATER REUSE SYSTEM

A domestic gray-water reuse system using bath and laundry waste waters to provide toilet flush water was designed and included in the Tech House. A schematic diagram of the system is shown in figure 10.

Ordinary household bleach was automatically dispensed to the collection tank for purification. Back washing of the collection tank was occasionally performed to clean out the sediment in the tank.

A diatomaceous earth filter, similar to that used for swimming pools, was used to remove the large particles and reduce the turbidity and foaming action induced by detergents.

Tap water was automatically fed into the collection tank when gray water was inadequate to meet the flush-water needs. When excess gray water became available and could not be collected in the storage tank, it was dumped into the sewage system.

Approximately 27,000 gallons of toilet flush water were required during the year, of which approximately 5,000 gallons were fresh water. An even larger portion of the flush-water needs could have been realized if the collection tank had been 140-gallon capacity, instead of 110. This would have minimized the amount of water dumped as a result of the laundering habits of the family. The water savings from the reuse system for the 1-year test amounted to 27 percent but, with a larger storage tank, it could have been about 33 percent.

The system operated satisfactorily during the live-in test. The family did not find its use objectionable. Sometimes the appearance of dye in the water the day after washing jeans would be evident. Some maintenance on a monthly basis for the cleaning of the filter and for back washing the system is required.

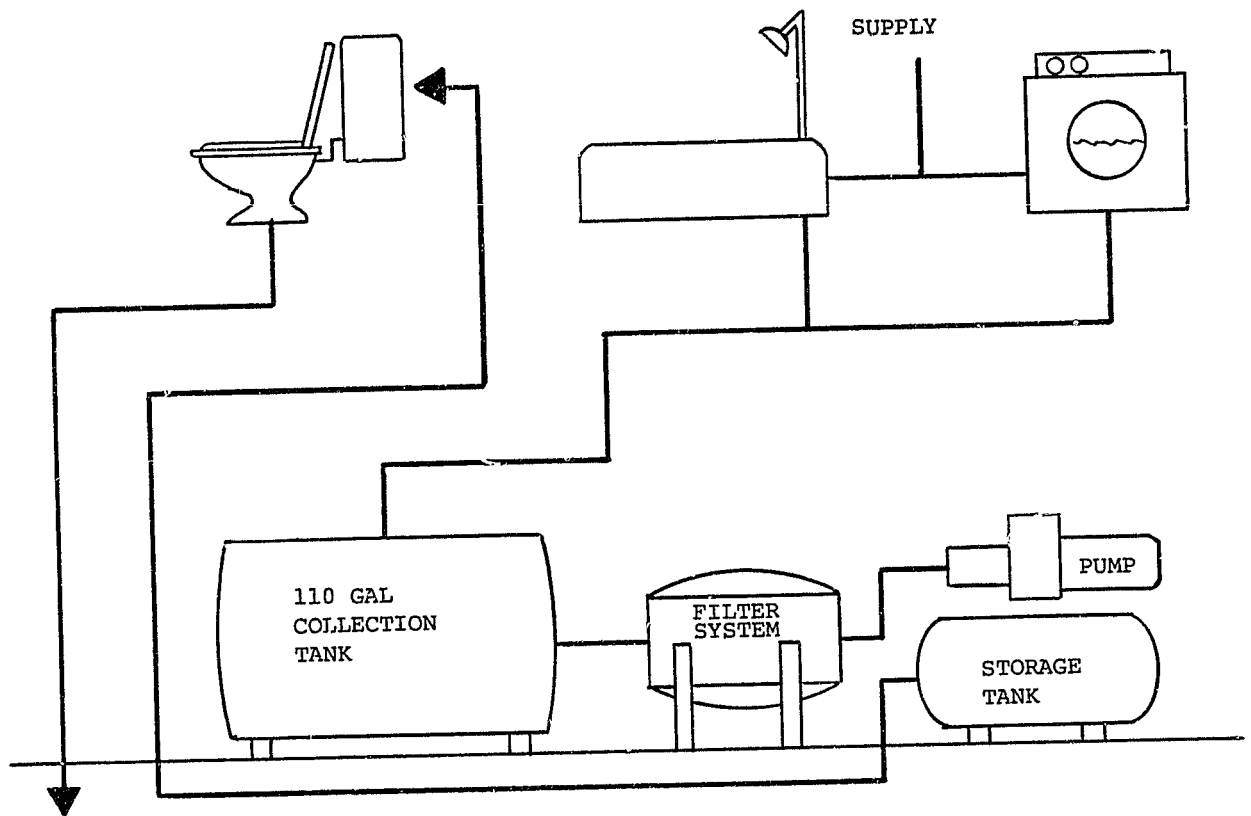


Figure 10 - Water Reuse System

### THE FAMILY EXPERIENCE

In general, the technology incorporated in the house was not objectionable to the family. There were some unusual noises generated by the water reuse system, but no more than would be experienced with a pumped well water system.

All technology systems were designed with a backup system in order to maintain the necessary essentials and comfort as a residence. Nevertheless, there was an occasional malfunction, which required patience and tolerance by the family.

The family particularly liked the double-pane, horizontally-opening windows in the Tech House. When they returned to their home in Florida, they had the same type of windows installed in their home, and they reported a significant savings in energy as witnessed in their heating and cooling energy bills.

### CONCLUDING REMARKS

The live-in test of the Tech House located at Langley Research Center in Hampton, Virginia, indicated that energy savings and water savings are possible with new-technology systems. Use of the house by a family for a year permitted data to be collected on the general operation and performance of the systems and on the effects of family lifestyles on technology utilization and payback. Comparisons of the energy systems of a Reference House in the Baltimore-Washington area with those of the Tech House were made. A combination of solar collectors and water-source heat pumps reduced the electricity required by about 50 percent. This reduction was less than expected because of less-than-normal sunshine coupled with a colder-than-average winter, as well as some design features of the system. An above-ground storage tank would prevent large heat losses to the ground experienced as a result of degradation of the tank insulation from ground water. Based on the test data, however, solar energy for space heating is still not cost effective.

Solar energy provided about one-third of the domestic hot water requirements. The actual energy required for domestic hot water was more than that projected because of a greater-than-expected consumption. A larger solar collector area and a larger solar preheat tank would be required to supply the hot water as used during the test. The family lifestyle (most water used early mornings and evenings) had an effect on the system's efficiency and should be incorporated into system design and component sizing. Properly sized and designed, a system for solar heating of domestic hot water is cost effective.

Recycling of wash and bath water for toilet flush reduced water consumption by about 27 percent. The general operation and performance of the system was acceptable to the family. Routine maintenance, about once a month, is required to clean the tank, replace the filter, and replenish the chlorine bleach used for purification. The size of the collection tank depends on family size and lifestyle. A 140-gallon tank instead of the 110-gallon tank used in the system would have enabled the collection of more of the waste water for toilet flush.

Thermal and architectural design features provide the biggest energy savings and provide the best payback on investment.

No attempt was made during the live-in test to change the family lifestyle. Some changes in today's lifestyles, such as optimum use of the shutters, greater use of the fireplace, keeping doors closed between zones and in vestibules, use of hot water during daytime hours for bathing and laundering, could result in greater savings.



## APPENDIX: HOUSE DESCRIPTION

This appendix contains the names and addresses of organizations from which NASA purchased services, materials, systems, etc., in connection with the advanced technology items used in the Technology Utilization House. The listing of these organizations is not to be construed as an endorsement or recommendation by NASA, but only as one available source. Where prices are included, they are those in effect prior to June 1976 and are provided only as general information.

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SOLAR ENERGY USE  
AND  
ENERGY CONSERVATION TECHNIQUES

HEATING

The heating system for Tech House utilizes solar energy to supply the major heating requirements through one of several modes of operation depending on heat requirements, weather conditions, and water temperatures in the storage tank. The major components in the heating system, shown in the schematic diagram (page 32), are the solar collectors where water passes through flat plates, thermal storage tank, heat pumps, and direct heat exchanger.

Solar energy is collected by 384 square feet of black flat-plate solar collectors mounted at an angle of 58 degrees on the south facing roof of Tech House. The solar collectors heat the water for heating the house or for raising the temperature of the water in a thermal storage tank, which is insulated and buried in the ground. The thermal storage tank has a 1900-gallon capacity and is used to store energy for use at night and on overcast days. The storage tank was designed to store enough energy to provide sufficient heat for up to 5 consecutive days. When direct solar heating is not available, a heat pump is used to transfer stored heat from the storage tank to the house. On clear days, if heat is needed in the house, hot water from the solar collectors is circulated directly through the direct heat exchanger where heat is transferred from the water to the air.

If heat is not required in the house, the hot water from the solar collectors is diverted to the thermal storage tank to increase the temperature of the stored water. At night and on overcast days when solar energy is not collected, heat is supplied to the house by circulating hot water from the storage tank through the direct heat exchanger. When the temperature of the stored water drops below 110°F, the heat pumps transfer heat from the storage tank to the house. If the stored water temperature drops below 55°F, two wells (shown on the schematic, page 32) provide an additional source of water from which the heat pumps can transfer heat to the house. However, the stored water temperature is not likely to fall to the 55°F level unless there are 10 to 15 continuous overcast days with extremely low temperatures.

As discussed in a subsequent section on the fireplace, water can also be heated by circulation through the fireplace grate/coil. The heated water is then circulated through the direct heat exchanger or to the storage tank.

Numerous solenoid valves and several pumps are utilized in the heating system. These valves and pumps are operated by differential temperature flow controllers, which provide electrical signals when preset temperature differentials exist within the system.

The ductwork which distributes the warm air throughout the house is part of a zone control system using advanced controls to accurately and automatically control the temperatures in the three areas of living, sleeping, and bathing. This system for control of heating and cooling will result in substantial energy savings. A computer monitors inside temperatures and, by means of a computer program written to reflect the family's activities, heats only the rooms being used. This computer can be made not much larger than a pocket

calculator. During winter days, the module containing the living areas will be warm, while the module with the bedrooms will be cool. At bedtime, the program will be reversed, with warm bedrooms and bathrooms and cool living areas. A manual override will return control of the system to the occupant during an emergency. For research purposes of NASA, the equipment shown on page 34 was installed in the garage to record the effectiveness of the different systems and their components. This would normally not be in a home.

The heating system in Tech House is more complicated than would be necessary for the normal home because of the experimental features incorporated for evaluation purposes. The four possible modes of heating could be reduced to supplying solar energy to the storage tank in a closed system and then utilizing a second closed system, including the heat pump, to transfer heat to the house. The backup would be electrical heaters installed in the heat pump.

Additional energy-conserving features incorporated into Tech House include the entry vestibules and the south window areas with roof overhang.

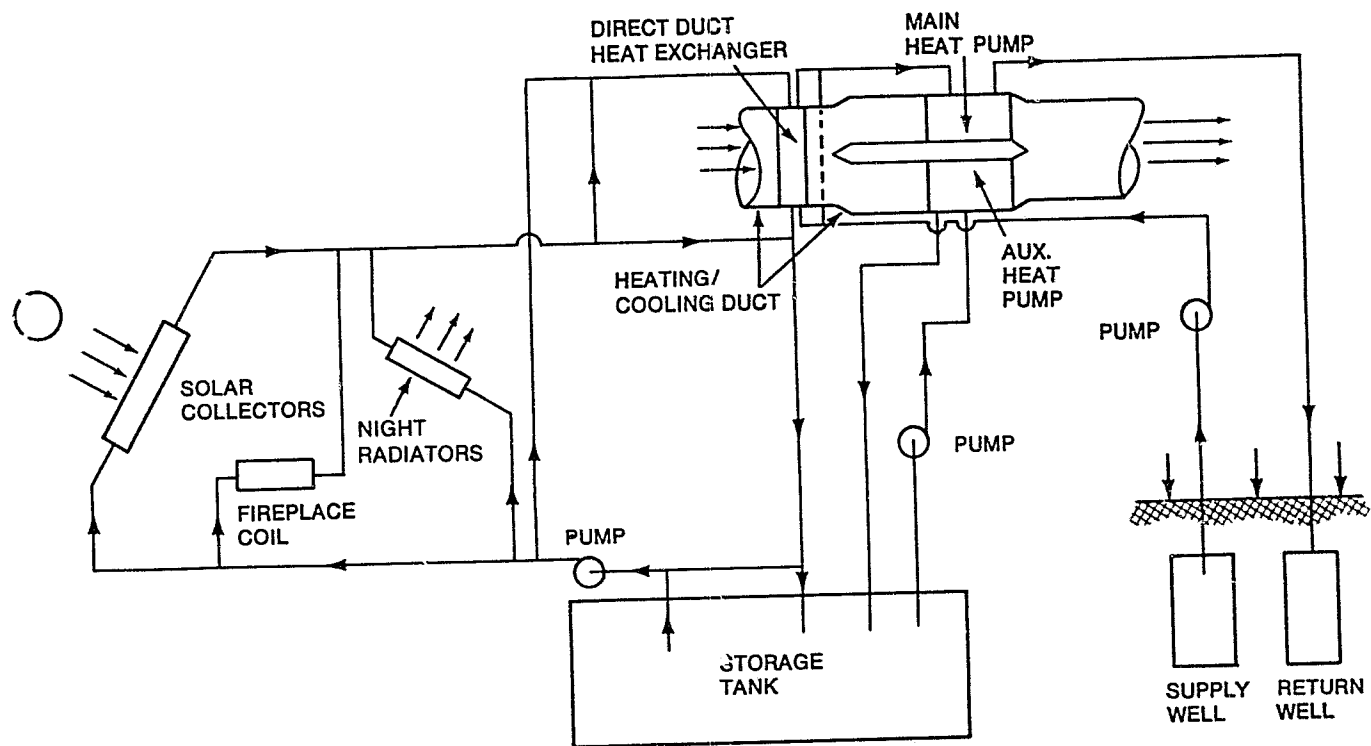
The entry vestibules at the front and rear of the Tech House hallway act as air locks and prevent the loss of large quantities of heated or cooled air from inside the house while the outside door is open. The reduction in heated or cooled air loss becomes significant during extremely cold winter days or hot summer days.

The large window area on the south wall, the overhanging roof, and the exterior retractable shutters result in significant energy savings. The large glass area allows solar energy to be transmitted into the house through the windows during the winter days. At night, the shutters keep the heat from escaping from the house. The roof overhang was designed to allow the sun to shine through the south windows in the winter when heat is needed, but to shade the windows from the summer sun when it is desirable to keep the heat gain low.

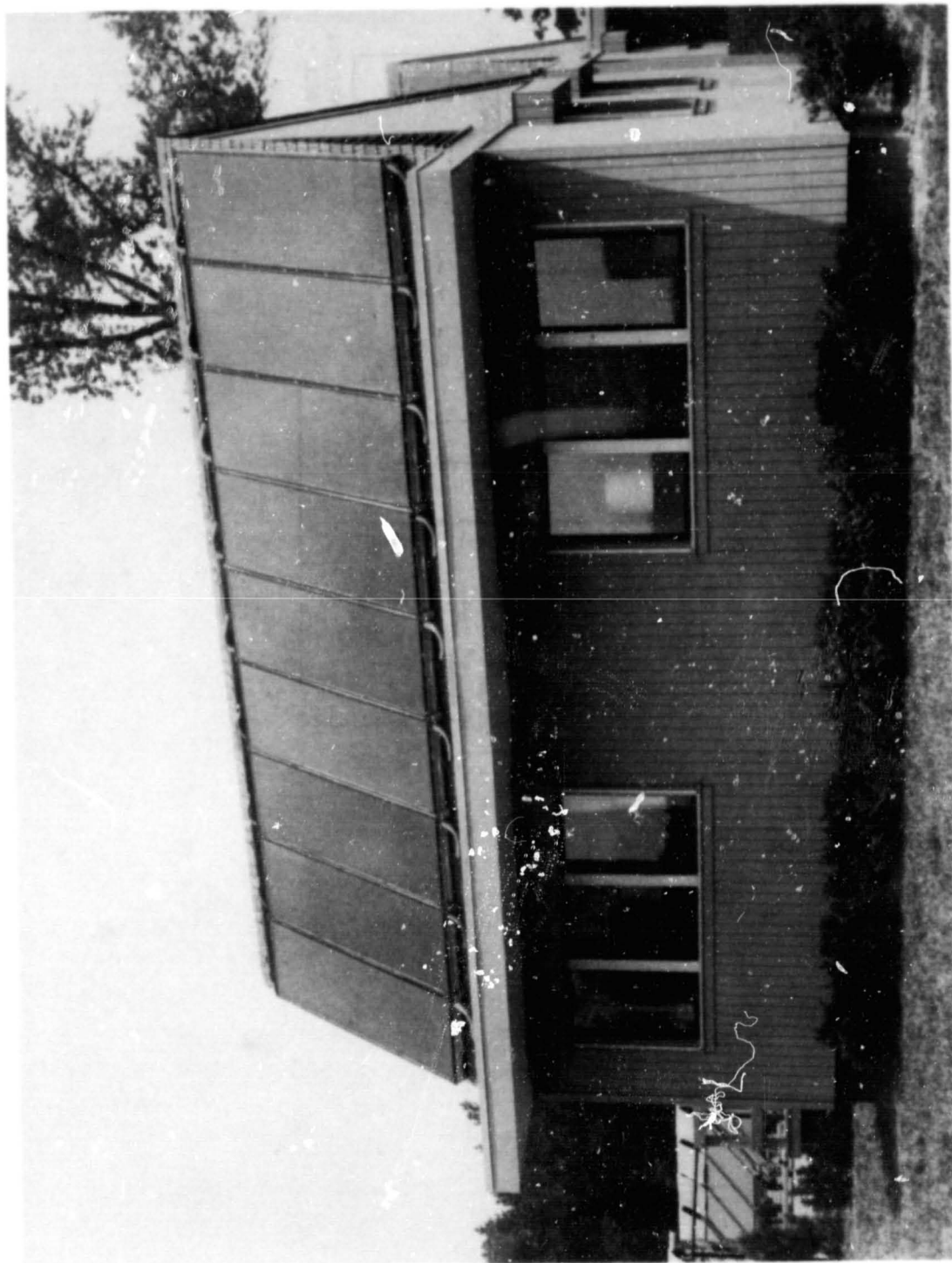
The water source heat pumps used in the Tech House were purchased from:

Florida Heat Pump Corporation  
610 Southwest 12th Avenue  
Pompano Beach, Florida 33060  
Telephone: (305) 781-0830

Simplified Diagram of Heating and Cooling System

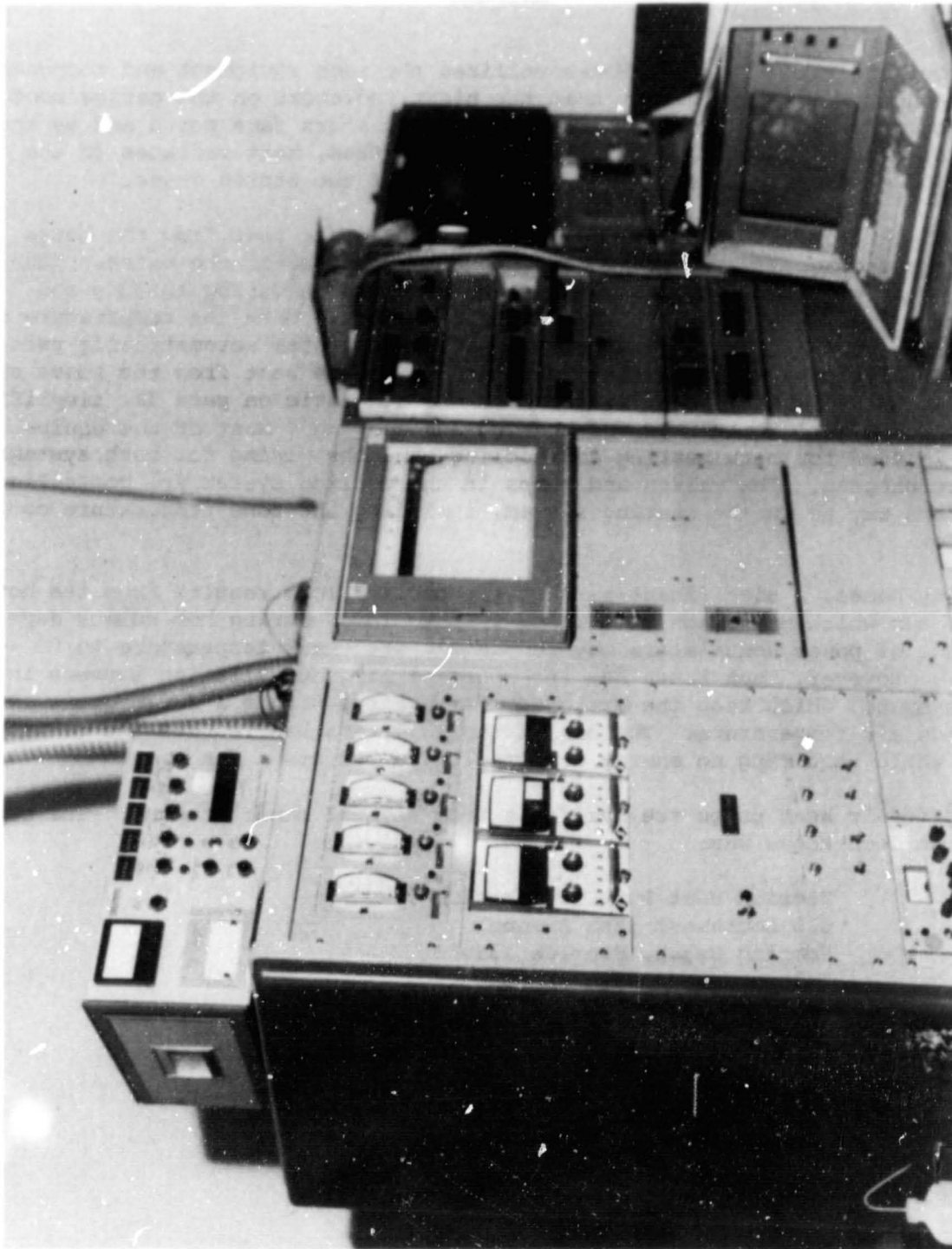


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Solar Collectors

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\*Systems Monitoring Equipment

\*For NASA research purposes only.  
Would not normally be in home.

### COOLING

The cooling system for Tech House utilizes the same equipment and components as the heating system, except that the night radiators on the garage roof replace the solar collectors. These night radiators face north and as the hot water from the storage tank circulates through them, heat radiates to the atmosphere, thereby lowering the temperature of the stored water.

To cool the house, the heat pump is used to transfer heat from the house into the storage tank where it raises the temperature of the water. Thus, cooling is provided by raising the water temperature during the day and lowering it at night by using the night radiators. When the temperature of the water in the storage tank reaches 90°F, the system automatically switches to the wells as a source of 55°F water to which the heat from the house can be transferred. The system is shown in the schematic on page 32, simplified to show the components used for heating and cooling. Most of the equipment is used for both heating and cooling, and the piping for both systems is interconnected. The valves and pumps in the cooling system are controlled in the same way as in the heating system, including the zone temperature control system.

In many homes, a significant part of the cooling load results from the hot attic air which may reach temperatures up to 160°F during hot summer days. The use of power ventilators may reduce the attic air temperature to 90 - 110°F. However, Tech House has incorporated large ventilation louvers in the attic space, which keep the attic air temperature within a few degrees of the outside air temperature. The use of these louvers has reduced the cooling load while requiring no energy consumption to operate a fan.

Water-to-air heat pumps are available from several manufacturers. The supplier for the Tech House was:

Florida Heat Pump Corporation  
610 Southwest 12th Avenue  
Pompano Beach, Florida 33060  
Telephone: (305) 781-0830

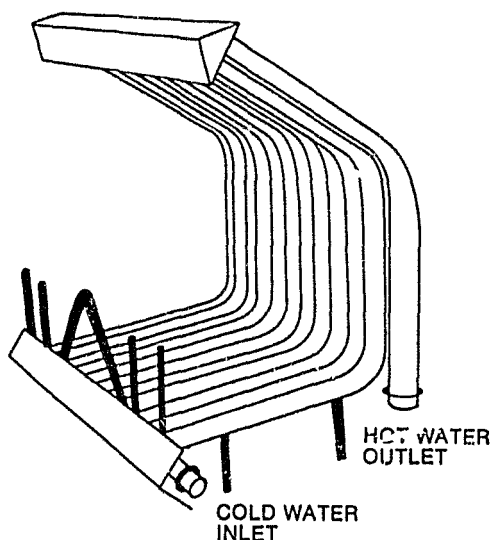


## FIREPLACE

The fireplace, as utilized in Tech House, is an integral part of the heating system. Fresh combustion air from outside, rather than using already heated air from inside the room as conventional fireplaces do, is supplied by a duct directly to the firebox, thereby significantly reducing heat loss up the chimney. Room-heating capacity is further increased by the use of a double-wall metal firebox which allows some escaping energy to be returned to the room. Additionally, the temperature of the water in the storage tank can be increased by circulating it through the fireplace grate, which is a coil through which water can flow. These special features increase the efficiency of the fireplace from the usual 10 percent to about 50 percent.

The water circulating grate/coil used in the fireplace was fabricated at the Langley Research Center. It is expected to recover 38,000 BTU's per hour from an available 95,000-BTU log fire. Water grate systems using similar concepts are available commercially, can be installed in existing fireplaces, and are adaptable to hot water, forced air, or electrically heated homes. One manufacturer claims a 40-percent recovery of heat generated by the fireplace fire.

Manufacturer of Hydrohearth: Ridgway Steel Fabricators, Inc.  
Box 382  
Ridgway, Pennsylvania 15853  
Telephone: (814) 776-1323 or 776-1324



Hydrohearth by Ridgway  
Steel Fabricators

## EXTERIOR RETRACTABLE SHUTTERS

The exterior retractable shutters\* used on Tech House windows provide energy savings by holding heat in during the winter and keeping heat out during the summer. The shutters can be raised or lowered in seconds from inside the house by either an electric motor or a hand-operated crank. Additional benefits achieved through installation of exterior retractable shutters are:

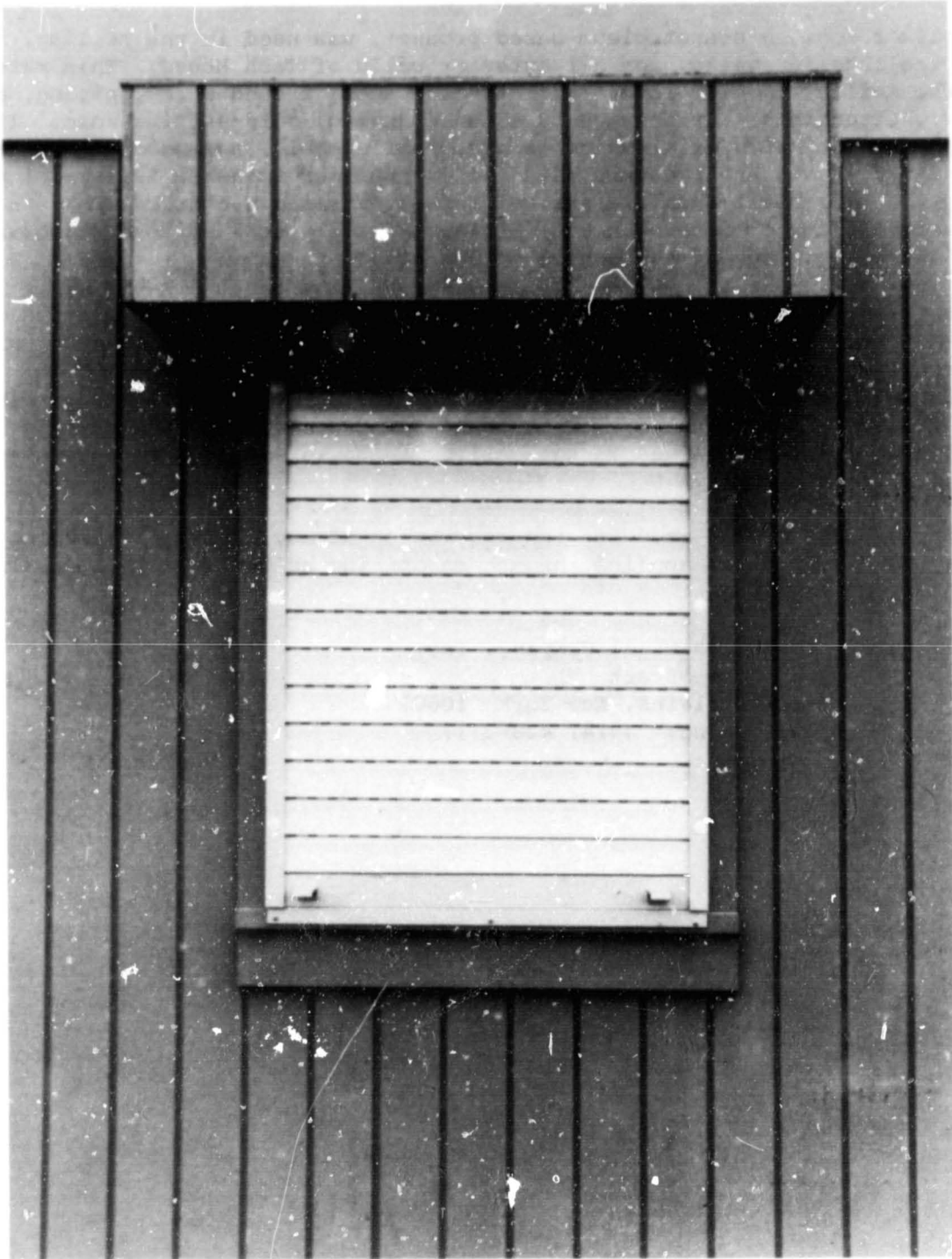
- Noise Reduction. The shutters provide an additional barrier to noise transmission.
- Security Protection. When lowered, the shutters self-lock and cannot be raised from outside the house.
- Light Control. The shutters can be adjusted to expose vents between the slats to admit soft light, or they can be closed completely to shut out all light. Exposure of the vents will also permit air to flow through the shutters.
- Storm Protection. Closed shutters are a deterrent to flying debris.

Manufacturer: Pease Company  
2001 Troy Avenue  
New Castle, Indiana 47362  
Telephone: (317) 529-1700

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\*The exterior retractable shutters are an example of cost-effective technology used in Tech House which was not directly related to the aerospace program.

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Exterior Shutter with Vents Exposed - Shutter Not Completely Closed

## INSULATION

Tripolymer foam, a nonpetroleum-based product, was used in the ceiling, selected interior walls, and all exterior walls of Tech House. This material has the ability to flow into a variety of spaces, around wires, piping, and other obstructions. Tripolymer is a nonexpanding, cold-setting foam. It is a good insulating material which is also nonflammable, rodent resistant, and presents an effective barrier to noise transmission. Tripolymer will self-insulate against fire by forming a charred crust when exposed to flame or intense heat. It is completely self-extinguishing with no flame advance beyond the source of ignition.

The exterior walls were constructed using 2- by 6-inch studs on 24-inch centers instead of the usual 2- by 4-inch studs on 16-inch centers so that 5½ inches of Tripolymer insulation could be installed in the exterior walls. The insulating qualities of Tripolymer foam are indicated by the thermal resistance or R value. The R value for the 5½ inches of Tripolymer in the exterior walls is 25 and for the 7½ inches in the ceiling is 34 as compared to fiberglass of 19 and 27, respectively.

Tripolymer can also be used for the insulation of any cavity in existing structures, since it can be applied through an opening as small as 1½ inches in diameter.

Manufacturer: C. P. Chemical Company, Inc.  
25 Home Street  
White Plains, New York 10606  
Telephone: (914) 428-2517

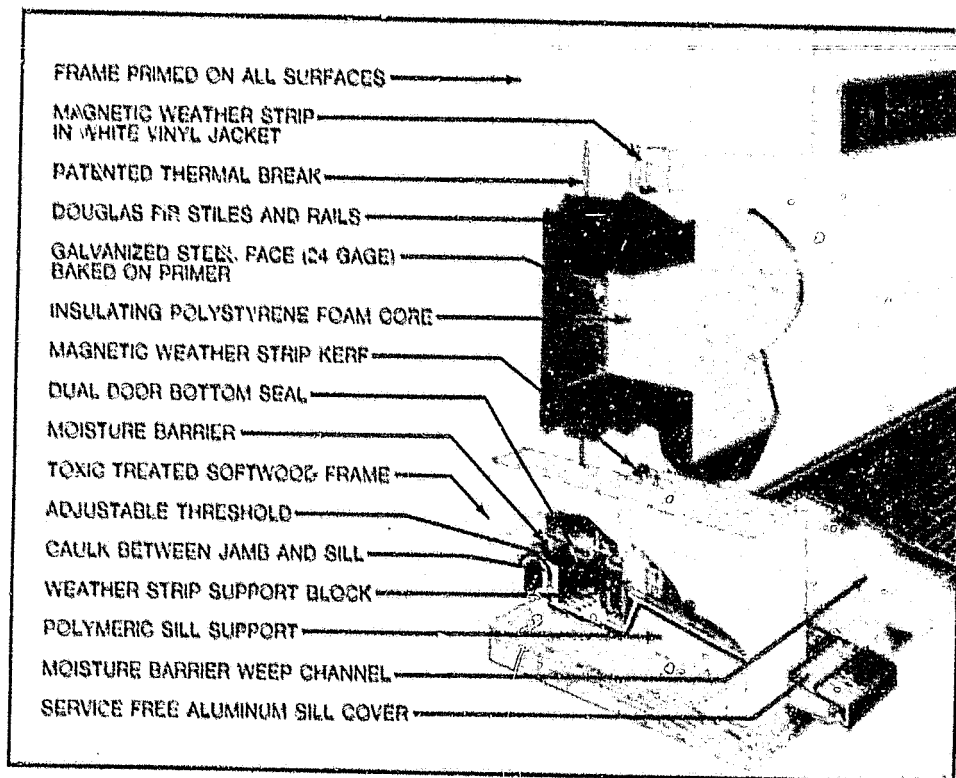
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EXTERIOR DOORS

The exterior doors on Tech House have steel surfaces with polystyrene foam cores and magnetic weather-stripping.

The steel surfaces are hot-dipped galvanized for rust and corrosion resistance. The expanded polystyrene foam core provides superior insulation and maintains a separation of the metal panels so that heat and cold cannot be transferred from one side to the other. An adjustable sill provides a positive seal against the weatherstrip in the bottom of the closed door. Each of these metal doors used will save approximately \$39 a year in energy costs.

Manufacturer: Pease Company  
900 Laurel Avenue  
Hamilton, Ohio 45023  
Telephone: (513) 867-3333



Pease Ever-Strait Door

### ENERGY SAVING APPLIANCES

A study was made by the Architect-Engineer (A/E) design team to determine which appliances were most energy efficient and cost effective for use in Tech House. From this study, it was determined that various manufacturers generally had one unit which was energy efficient, while the other units were not as energy efficient as those of other manufacturers. Based on the study, the A/E design team recommended appliances from several manufacturers. The final selection was based on overall cost effectiveness of the complete set of appliances as purchased from one manufacturer.

The use of a microwave oven is especially recommended as an energy-saving appliance, because foods cooked in a microwave oven require less time for cooking, thereby using less electricity. Also, the use of a microwave oven adds little or no heat to its surroundings while cooking.

Additionally, a Super Skewer is used to help reduce energy consumption by speeding up cooking of such items as roasts. This item is a heat pipe which utilizes the capillary action of a liquid in a sealed pipe to transfer heat. The Super Skewer is inserted into the roast and transfers heat from the air in the oven to the inside of the roast, allowing it to cook from both the inside and outside.

The Super Skewer in the Tech House was purchased from:

Isothermics, Inc.  
P.O. Box 86  
Augusta, NJ 07822  
Telephone: (201) 383-3500

The 1976 price was \$10 per skewer.

## WATER REUSE SYSTEM

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### WATER REUSE SYSTEM

An experimental program was conducted at Langley Research Center some time ago to determine if spacecraft systems could be modified to process household waste water. A typical household for a family of four was set up with appliances and fixtures to produce waste water. Instead of releasing bath and laundry water into sewer lines, the water was filtered and chlorinated for reuse as toilet flush water. The experiment revealed that this single step could easily reduce water consumption by 60 to 100 gallons a day.

The water reuse system used in Tech House reduces water consumption by half when combined with other water saving methods. Water from bathtub, shower, and laundry equipment is collected in a holding tank, chlorinated, filtered, and recycled, as shown in the schematic diagram on page 45, for use as water for toilet flushing. Even though the toilet flush water is safe enough for possible tasting by children or pets, to alleviate health and safety concerns of the average homeowner, the drinking water system is entirely separate from the recycled water system.

All waste from toilets goes directly to the sewer, as does any overflow from the collection tank. One additional benefit resulting from reusing the wash water is that a trace amount of detergent remains in the recycled water and tends to keep the toilet bowls clean.

The overall reduction in requirements for water in and waste outflow also reduces requirements for community sewage systems, treatment plants, and water supply systems.

The completed experimental programs have proven that the advantages of this system outweigh any disadvantages, such as initial cost, space requirements, and cost of maintenance.

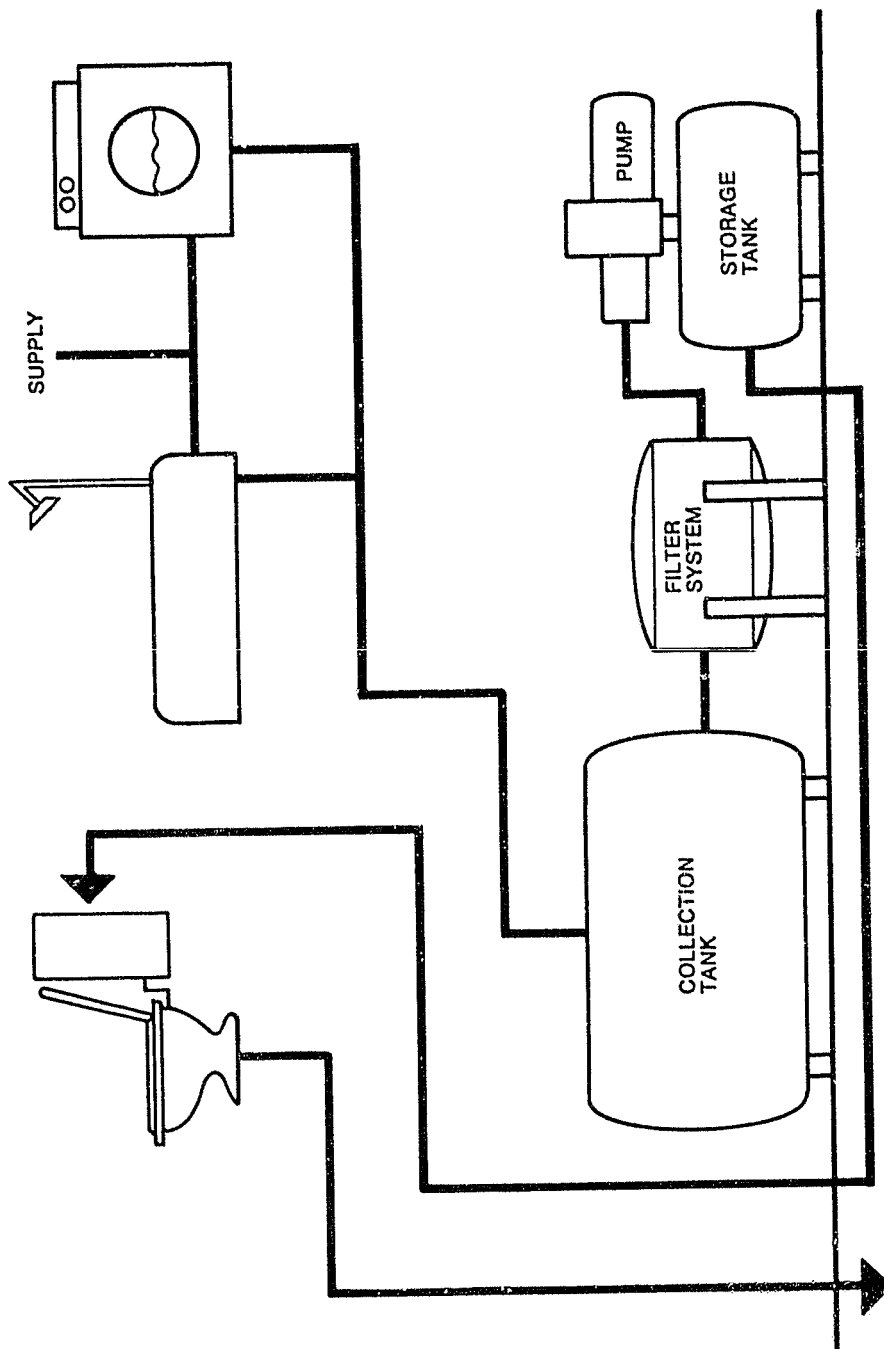
Material for the water reuse system is commercially available and was purchased at a cost of \$450.

Water-Cyk Corporation plans on marketing a water reuse system in 1980. We are not aware of their final design and cannot endorse their product. Details of the system may be requested from:

The Water-Cyk Corporation  
512 Maple Avenue, West  
Vienna, Virginia 22180  
Telephone: (703) 938-9070

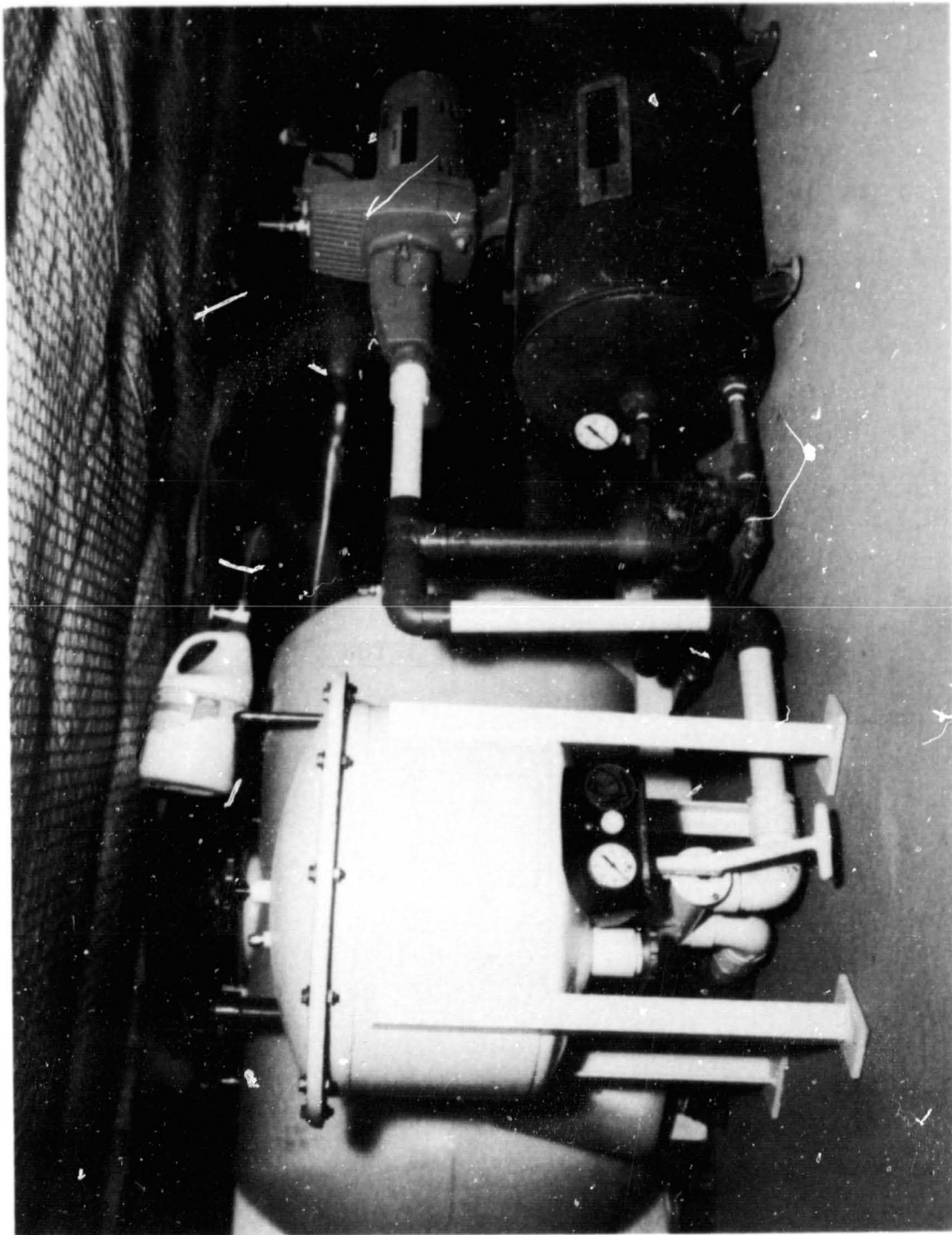
A copy of the report pertaining to the experimental water reuse program conducted by this Center may be obtained from the North Carolina Science and Technology Research Center whose address appears on page 77. The report may be obtained at cost. Ask for NASA TN D-7937, "Processing of Combined Domestic Bath and Laundry Waste Waters for Reuse as Commode Flushing Water."





Water Reuse System

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Water Reuse System Equipment

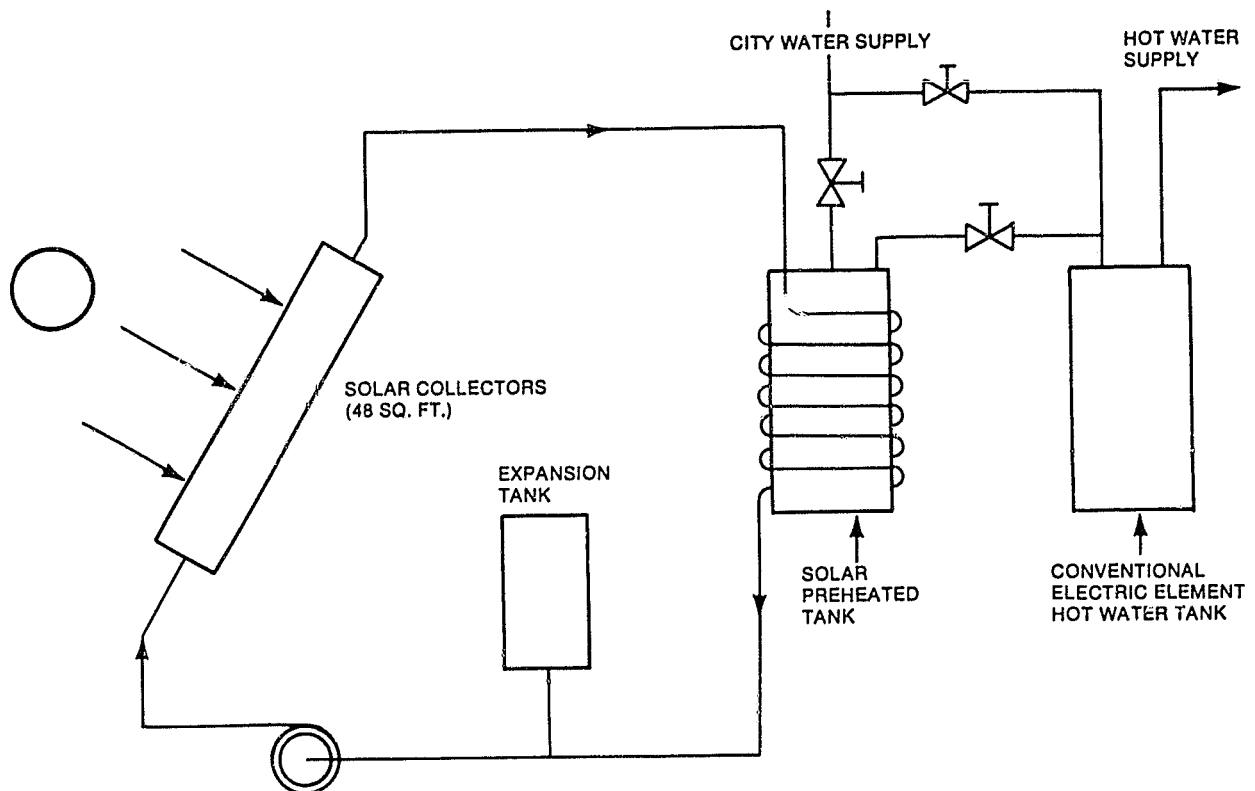
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DOMESTIC HOT WATER SYSTEM

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### DOMESTIC HOT WATER SYSTEM

Tech House has two domestic hot water tanks located in the house-to-garage passageway. One tank contains a heat exchanger that uses solar energy to preheat incoming water to approximately 140°F. This is a closed-loop system, shown below, with 48 square feet of solar collectors, a heat exchanger, and a pump to move the water around the loop. The heated water then goes to the electric hot water heater, then to the user. If large amounts of hot water are used and the water temperature drops below the thermostat setting on the hot water tank, the water temperature is raised by electrical resistance heating to the desired temperature. Hot water heaters are available, for use in solar systems, which contain both the heat exchanger and the electric resistance heaters, thus eliminating the need for two tanks.



Solar Hot Water System

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SECURITY SYSTEMS

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INTERIOR SECURITY SYSTEM

This system includes detectors at windows, doors, and under carpets as well as the personal security system, "Scan." The system is operated by house-hold power, or can be adapted for operation by a 12-volt battery.

The detectors at the windows are wires woven in the screens, which must be cut or removed to gain access through the window. The alarm is activated when the wires are cut or the window screen removed. The detectors under the carpets are pressure-sensitive pads which set off the same alarm. The detector pads at the three outside doors have a built-in delay which gives the occupant time to secure the system before the alarm sounds after entering the house. When the occupant enters the code number on one of the digital panel devices, any attempt to break into the house will set off the alarm.

Muggings and burglaries often occur when a homeowner is occupied in opening the house door in the dark, from an assailant that was hiding in the brush. To light dark areas at night before entering the house, the "Scan" pocket transmitter, the size of a fountain pen, can transmit an ultrasonic signal which will turn the porch light on from a distance of about 30 feet.

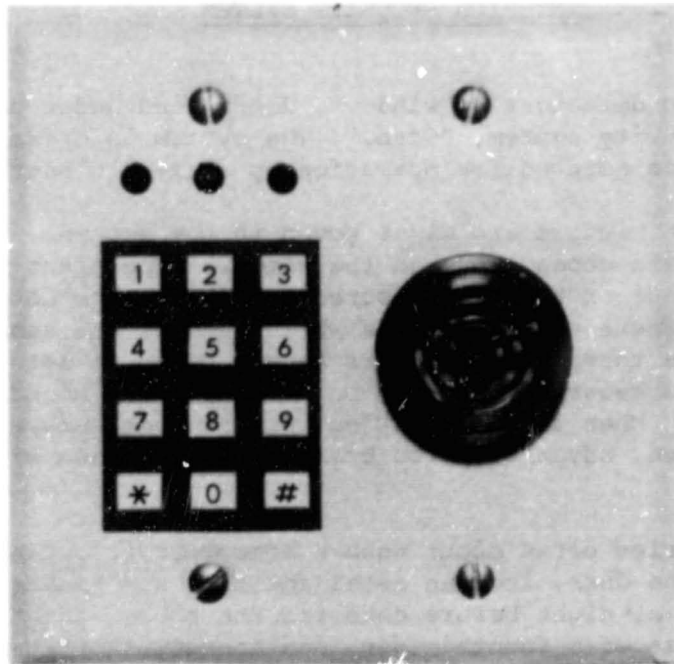
Manufacturer of "Scan"  
and Interior Security  
System:

Sentry Products, Inc.  
2225 Martin Avenue, Suite J  
Santa Clara, California 95050  
Telephone: (408) 727-1866

Installed by:

Honeywell Detection Systems  
2400 Granby Street  
Norfolk, Virginia 23517  
Telephone: (804) 622-1378

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Interior Security System Control Panel



Security Wired Screens

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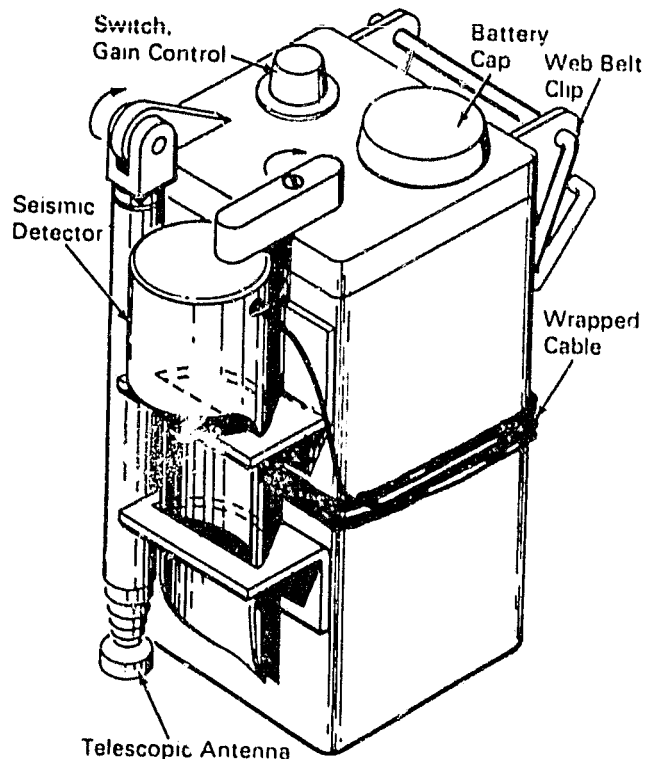
Pressure-Sensitive Pads



### EXTERIOR SECURITY SYSTEM

The exterior security system uses a seismic detector, similar to those used on the moon, to determine density and thickness. The seismic detector is planted in the ground and connected by cable to an electronic package enclosed in a water-tight container. The range of the seismic sensor is 80 meters (262 feet), and the movement of an intruder within that range causes a coil to vibrate. The amplitude and duration of the vibration depends on the intensity of the footstep impulse. The vibration of the moving coil sensor generates a voltage impulse which is amplified and transmitted to a remote FM receiver. The receiver emits a single tone burst for each footstep of a slow-walking intruder, while a running intruder will cause a continuous tone, with periodic variations indicating each footstep.

This system was fabricated at NASA's Ames Research Center and is expected to be available commercially in the near future. Information about this detector system may be obtained by requesting NASA Tech Brief 70-10638 and the Technical Support Package from the Technology Utilization Office, NASA Ames Research Center, Code AU:240-2, Moffett Field, California 94035.



Intruder Detection System

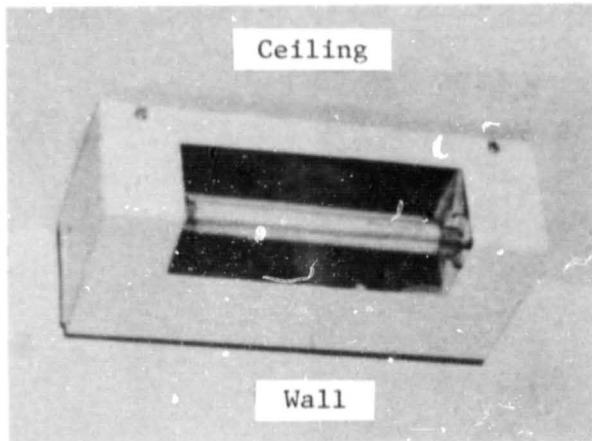
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EMERGENCY LIGHT SYSTEM

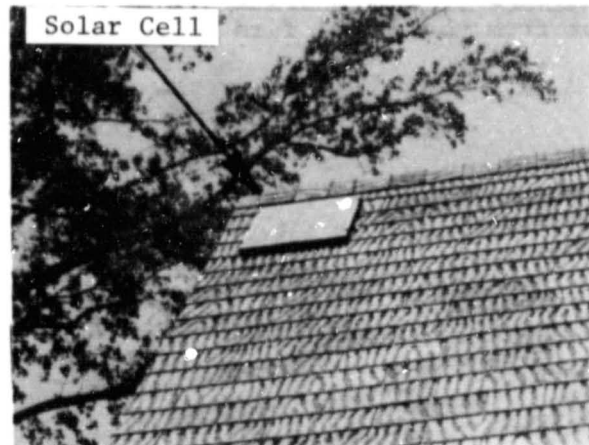
The multimode electronic lighting "Satellight" used in the Tech House emergency lighting system features the high efficiency and long life of fluorescent lamps, as well as extremely high light output for extremely low energy drain. The technology for this system was developed at NASA's Marshall Space Flight Center for providing light for such space vehicles as Skylab. It utilizes low-voltage, high-frequency power generated by self-contained, solid-state electronic lamp drives powered by a 12-volt battery, and is used during times of power failure to provide an even illumination that is more than adequate for safety and security. The battery, charged by a solar cell located on the roof of the garage, powers the system used in Tech House.

According to the company, UDEC lights are sold in systems. A system is comprised of one master battery module and four area or exit lights. The UDEC light systems are not (in their present configuration) designed or priced for the home market.

Manufacturer: UDEC Corporation  
223 Crescent Street  
Waltham, Massachusetts 02154  
Telephone: (617) 899-6400



Emergency Lighting Module



Solar Cell on Garage Roof

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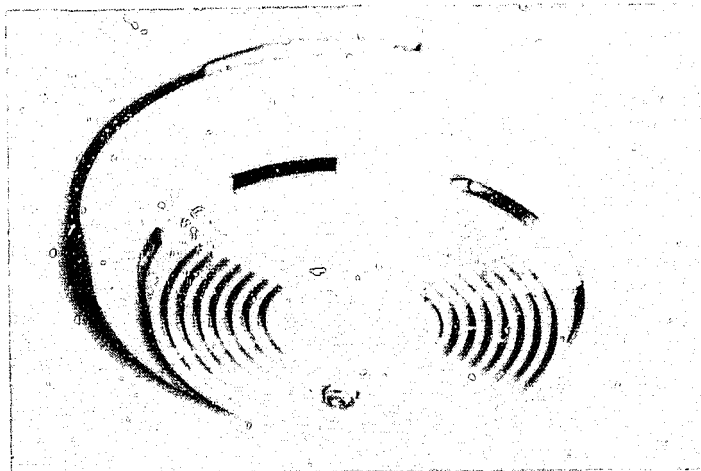
SMOKE DETECTION

The smoke detector used in Tech House is a sensitive detector which senses combustion products before they are noticeable to occupants and, when activated, will sound a horn which will awaken even the soundest sleeper, allowing adequate time for escape from the building. There are approximately 20 brands of smoke detectors on the market, ranging in price from approximately \$15 to \$85.

There are two types of smoke detectors commonly used in the home: ionization detectors and photoelectric detectors. Ionization detectors use a radioactive source to transform the air inside them into a conductor of electric current. A small current passes through this "ionized" air. When smoke particles enter the detector, they impede the flow of current. Electronic circuitry monitors the current reduction and sets off an alarm when the current gets too low.

Photoelectric detectors have a lamp that directs a light beam into a chamber. The chamber contains a light-sensitive photocell, which is normally tucked out of the way of the lamp's direct beam. But when smoke enters the chamber, the smoke particles scatter the light beam. The photocell now "sees" the light and, at a preset point, sets off an alarm.

Of course, an alarm is only one aspect of a total program of home fire safety which should include fire-prevention measures, fire extinguishers (for small blazes only), and the development of alternate escape routes from the house in case of fire. Information on all these is available from the National Fire Protection Association (470 Atlantic Avenue, Boston, MA 02210), or from your local fire department.

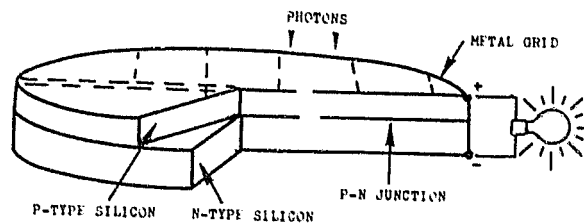


Smoke Detector

### AUXILIARY POWER SOLAR CELL

A solar cell is a device for converting light energy into electrical energy without moving parts through a phenomenon known as the "photovoltaic effect." Effective use of the solar cell began when NASA took it out of the laboratory and into limited production by making it the power source for satellites. The most efficient and inexpensive solar cells today are made of silicon, obtained from slicing round silicon ingots. Size is most important, as the power generated is proportionate to the area exposed to light (photon units). While photovoltage is independent of the area, the larger the solar cell, the higher the current will be. A single solar cell charges the Tech House battery which powers the driveway spotlight and the emergency indoor lighting. The cost of the solar cell used in Tech House is \$355.

Manufacturer: Solarex Corporation  
1335 Piccard Drive  
Rockville, Maryland 20850  
Telephone: (301) 948-0202



Solar Cell

### TORNADO DETECTOR

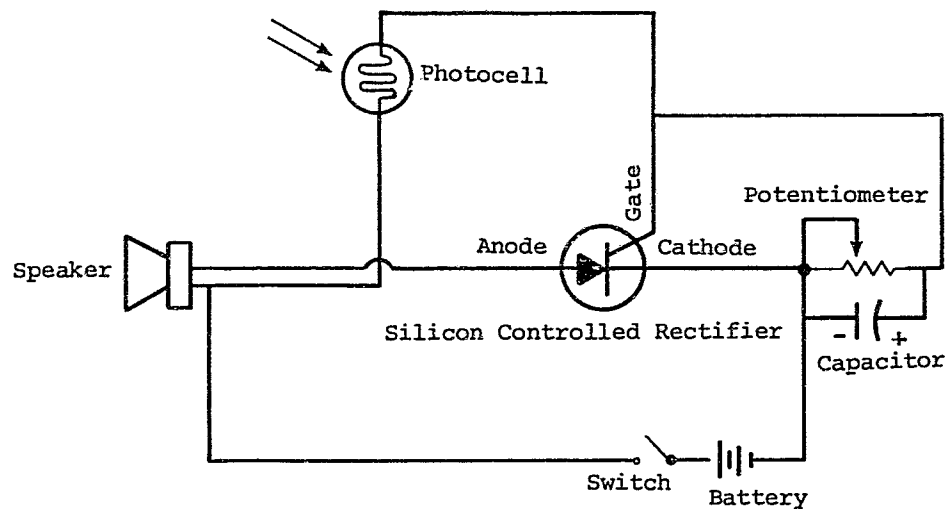
The tornado detector is a light-sensitive device, encapsulated in a suction cup, attached to the television picture tube. For the system to function, the television must be turned to an unused channel with the screen darkened. It is a simple, automatic alarm system that will sound an audible alarm upon the appearance of a tornado within 18 miles. The alarm signal will continue as long as the tornado is within 18 miles.

The device displayed at Tech House was built at NASA's Langley Research Center. A schematic containing a parts list is provided on page 62 for persons that are interested in building a tornado detector. A photograph of the device is shown on page 63.

Additional information concerning the tornado detector may be requested from the Technology Utilization Office, Code AT01, NASA Marshall Space Flight Center, Marshall Space Flight Center, Alabama 35812, telephone (205) 453-2224.

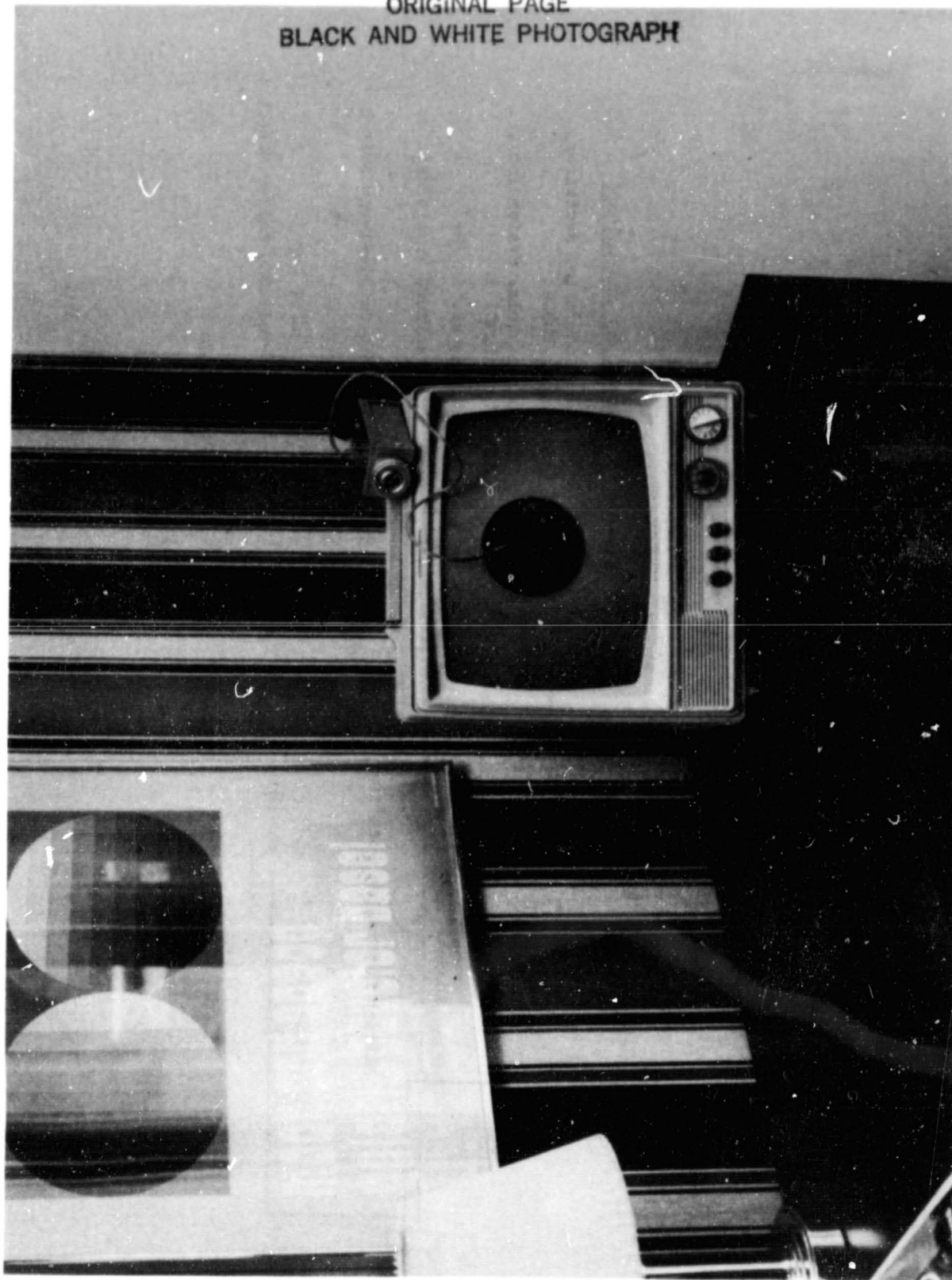
Note: This concept for tornado detection may not work for tornadoes with insufficient energy transmission.

## TORNADO DETECTOR



<u>No.</u> <u>Required</u>	<u>Parts (or Equivalent)</u>
1	Silicon Controlled Rectifier, Motorola, 2N5062
1	Photocell, Solar System Inc., Skokie, IL, D1 12439
1	Potentiometer, 5K Ohm
1	22µF. Capacitor, Tanelectric or Electro
1	Single-Pole Double-Throw Switch
1	9-Volt Battery
1	High-Voltage TV Cup
1	Speaker 6-Volt DC, Mallin Sonaler, 7542
1	Knob, Radio
1	Mini Box, 4" x 2"

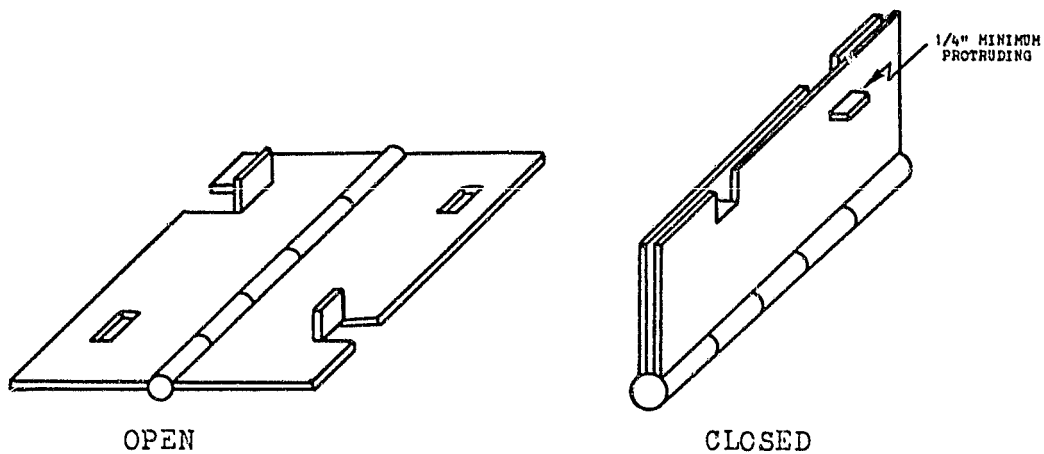
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Tornado Detector

### SELF-LOCKING HINGES

Self-locking hinges were used to secure the outward-opening exterior doors. This hinge was developed at NASA's John F. Kennedy Space Center to provide a mechanical locking device for doors and cabinets with exposed hinge pins. The hinge has dual tabs and slots that lock the hinge side of the door when it is closed to prevent its opening after removal of the hinge pins. The self-locking hinges used in Tech House were fabricated at Langley Research Center.



Self-Locking Hinge



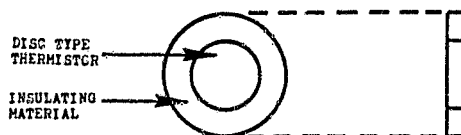
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MISCELLANEOUS TECHNICAL ITEMS

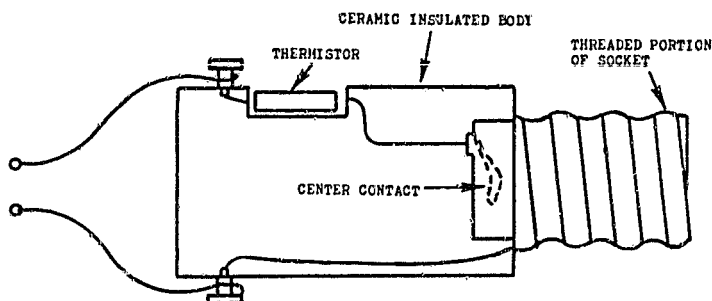
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### LIGHT BULB SAVER

The temperature-compensating thermistor, used to protect the Saturn booster from current surges during the Apollo project, serves as an electrical "shock absorber" to shield a light bulb against current surges. These thermistor discs, shown below, were installed in two Tech House light bulb sockets to increase the life of the light bulb by an expected 300 percent.



The thermistor disc is also available as an Integral Part of Lamp Socket as shown below:



The thermistor discs are available from the following companies:

Energy Saving Products  
6020 Calle De Felice  
P.O. Box 6694  
San Jose, CA 95150  
Telephone: (408) 267-8548

Energy Saving Products, Inc.  
3590 Edison Street, Suite 1  
San Mateo, CA 94403  
Telephone: (415) 341-6227

American Electro-Dynamics Corp.  
1 Penn Plaza, Suite 2830  
New York, NY 10001  
Telephone: (212) 594-1621

Blanden Corporation  
2707 Steven Drive  
Johnson City, TN 37601  
Telephone: (615) 928-8422

Bulb-Miser, Inc.  
14437 South Dixie Highway  
Miami, FL 33176  
Telephone: (305) 251-0485

American Guaranteed Lighting, Inc.  
5728 Ward Avenue  
Virginia Beach, VA 23455  
Telephone: (804) 464-9374

### TEMPER FOAM

Temper Foam is used in the seat cushion on the bench between the fireplace and the bookshelves in the living room. It is a flexible urethane foam material, developed to pad seats in the Apollo capsule. With the use of this material, the astronauts were comfortably able to withstand the forces of lift-off and the impact of splashdown. Temper Foam contours to a person's shape and distributes the weight evenly over the contact surface. It reduces fatigue because it absorbs 90 percent of sudden movement or vibration without shock or bounce. It softens with increased humidity and transpires moisture away from the body for cooler sitting comfort. It is ideal for orthopedic application and has been found to be an effective solution to preventing bed sores for persons who are bedridden or confined to extensive sitting.

Manufacturer: Edmont-Wilson  
1300 Walnut Street  
Coshocton, Ohio 43812  
Telephone: (614) 622-4311

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FLAT CONDUCTOR CABLE

The flat conductor cable (FCC) used in the Tech House living and dining room baseboard is similar to the cable used in the Apollo Lunar Scientific Experiment Package tests and represents technology used extensively in aircraft and spacecraft electrical systems. Rather than conventional round wiring, it resembles three flat wires printed on cardboard and can be installed as shown below. Its major attributes are ease of installation and modification, and requirements for less conductor metal for the same current carrying capacity.



Baseboard System Installation

Test installations such as Tech House have brought the FCC system shown on page 72 significantly closer to commercial readiness as a method of reducing the constantly rising cost of installing electrical systems in new and renovated buildings. Further, the flat conductors substantially reduce copper requirements and installation costs.

FCC undercarpet systems are not yet commercially available and the hardware is not yet listed by Underwriters' Laboratories. The system complies with article 328 of the 1978 National Electrical Code. Further inquiries may be directed to:

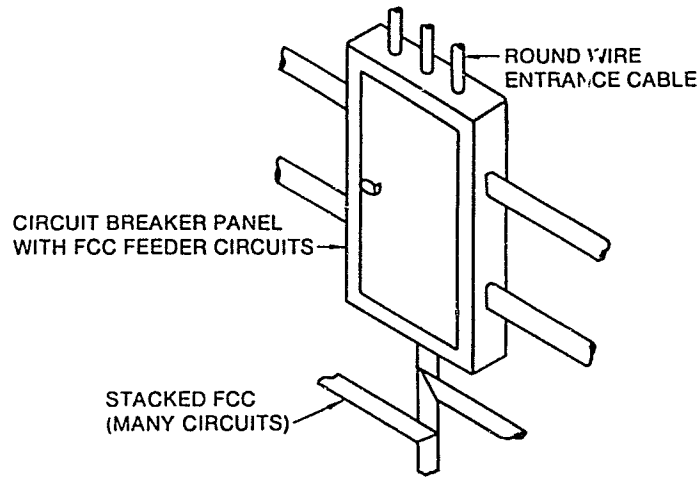
AMP, Inc.  
230 Commerce Drive  
Largo, Florida 33540

Thomas & Betts Company  
36 Butler Street  
Elizabeth, NJ 07207

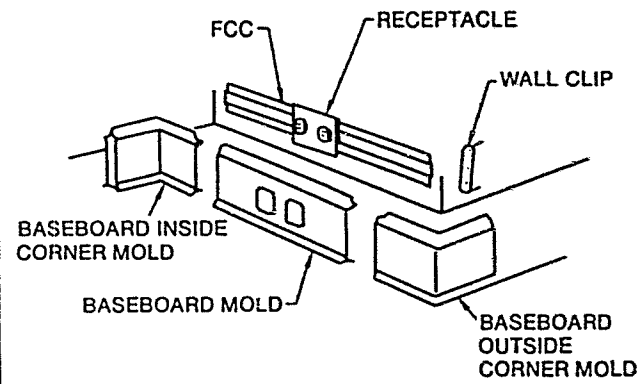
The baseboard system has not yet been approved.

The plastic baseboard covering, receptacles, corner pieces, and end pieces used in Tech House were furnished and installed by Marshall Space Flight Center, Huntsville, Alabama, while the cable itself was supplied by:

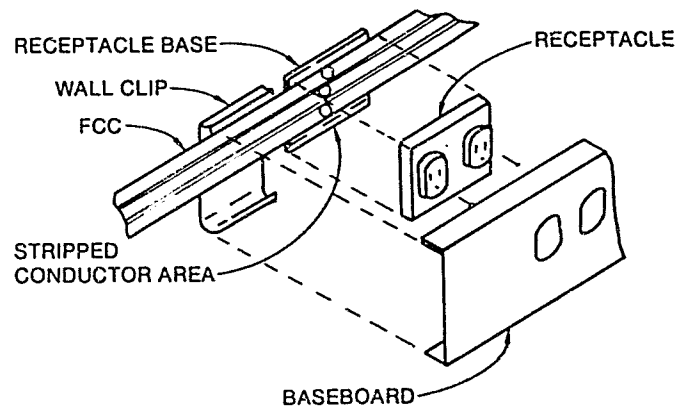
Parlex Corporation  
145 Milk Street  
Methuen, Massachusetts 01844  
Telephone: (617) 685-4341



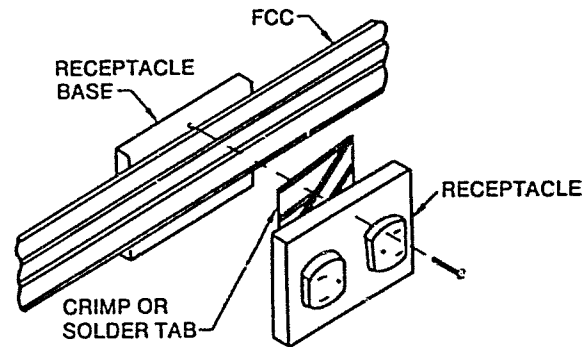
Circuit breaker panel



Snap-on cover baseboard system



Receptacle with pressure contacts



Receptacle with crimp or solder tab

### PREFABRICATED FLOOR AND WALL

A cast floor is used throughout Tech House, and a cast wall is used between the bathrooms and the master bedroom. These were installed to technically evaluate this form of construction, not because of any price competitiveness in the near future. The floor is a 2-inch, 5000 psi concrete plate, reinforced with welded wire fabric, and insulated with gypsum foam. The floor sections fit in a frame of lightweight steel shapes optimized to produce maximum performance from a minimum quantity of materials. The foam insulation in the floor is noncombustible and costs less than Fiberglas insulation of equivalent thickness.

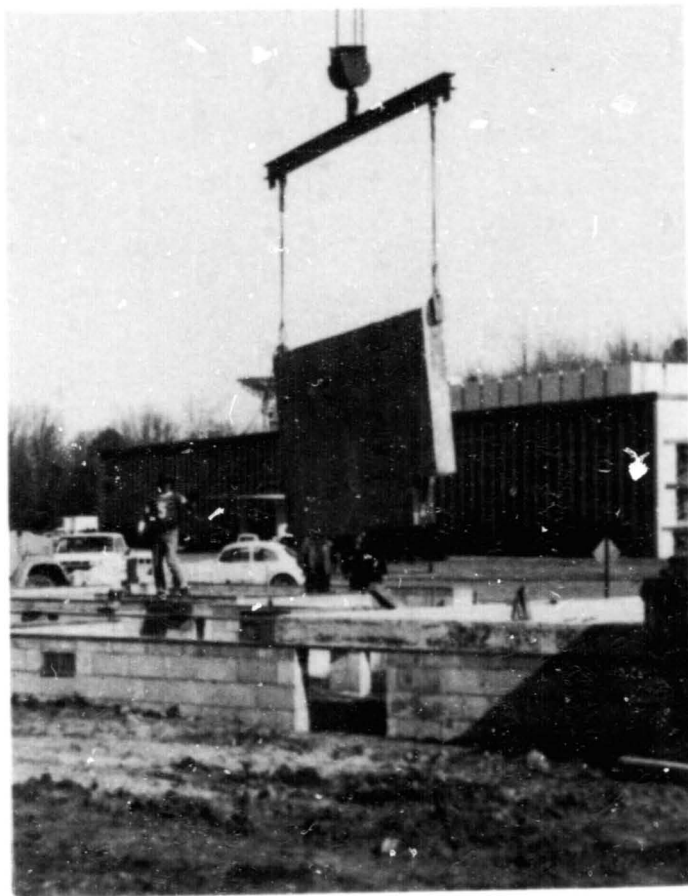
The prefabricated wall is a glass fiber reinforced gypsum and sand-cast wall mounted on a steel frame. The resultant wall is impact and fire resistant, with a uniform surface. The gypsum foam insulation fills all voids of the wall to reduce heat loss and reduce noise transmission. These floor and wall components are adaptable to conventional trim and finishing materials and were designed for integration with other prefabricated and conventionally built components.

These floor and wall components were procured from the General Electric Company, whose Re-entry and Environmental Systems Division has been developing advanced materials and industrialized technology for use in the construction industry.

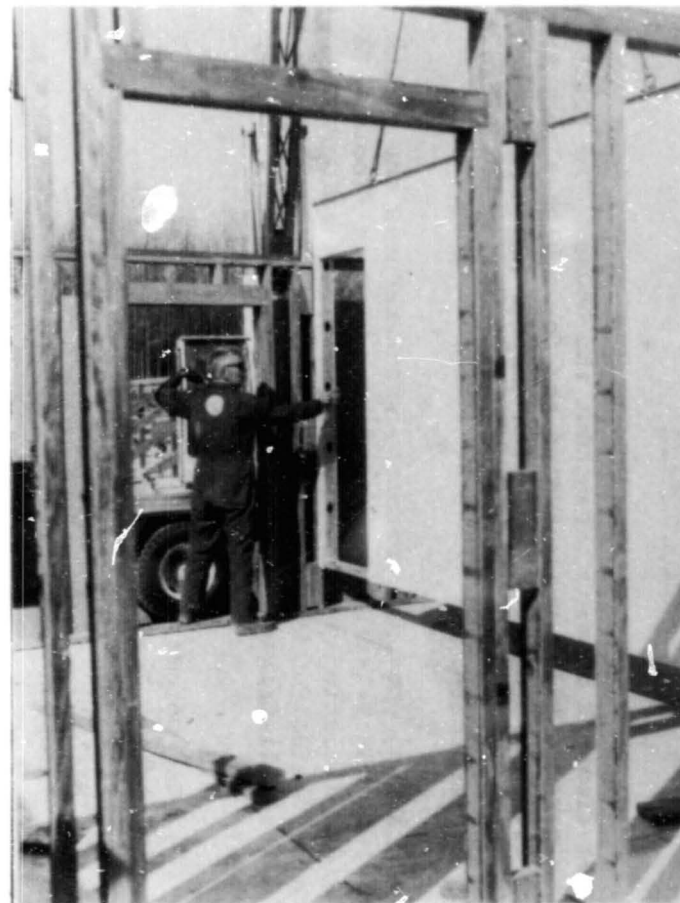
This construction can be competitive in price with conventional construction only when prefabricated sections are used throughout the house and several houses are erected at the same time. At this time, this type of construction has not been considered for isolated structures. It was found that when only the floor and a wall are installed in a custom home, as in Tech House, the cost of the crane to position the sections and the cost of drilling the floor for custom plumbing, heating, etc., resulted in increased costs over conventional construction by about three times. It is hoped, however, that results from analysis by NASA may allow a better understanding of its advantages as compared to its present and future price potential.

Information about these products may be requested from:

General Electric Company  
Re-Entry and Environmental Systems Division  
Product Information  
3198 Chestnut Street  
Philadelphia, Pennsylvania 19101  
Telephone: (215) 835-2669



Placement of Typical Floor Panel



Placement of Double-Cast Wall Panel

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### FLOOR COVERING

The concrete cast floor is covered throughout the house. The bathroom floors are covered with ceramic tile; the entrance and foyer with slate; the bedrooms, hallway, living and dining rooms with carpet; and the kitchen with a thick foamed-backed sheet vinyl having a urethane coating which has a natural shine requiring minimum care.

The thick-foamed backing provides softness, which reduces the tiring that is associated with constant walking or standing on concrete floors. This floor covering is a GAF Corporation product and is identified as GAF STAR Citation, Santana pattern 50006 (Golden Feather). Additional information can be obtained from a local distributor of GAF floor covering materials or from the following address:

GAF Corporation  
Attn: James M. Cloney, Senior Vice Pres.  
1101 15th Street, N.W.  
Washington, DC 20005  
Telephone: (202) 659-9545

#### HOUSING AND URBAN DEVELOPMENT STUDS

The 2- by 4-inch studs used to frame the interior walls of Tech House were reconstituted from sawdust, thereby utilizing scrap or previously discarded material and reducing new timber cutting. The 2-inch sides of the reconstituted studs were faced with plywood to facilitate nailing.

The Technology Utilization House Study Report, NASA CR-144896, may be purchased from the following address:

North Carolina Science and Technology Research Center  
P.O. Box 12235  
Research Triangle Park, NC 27709  
Telephone: (919) 549-0671

A complete set of drawings and specifications of the Tech House are available for \$10 per set from the above address. In addition, reports generated on the operation of the various systems will be available from the above address as they become available.